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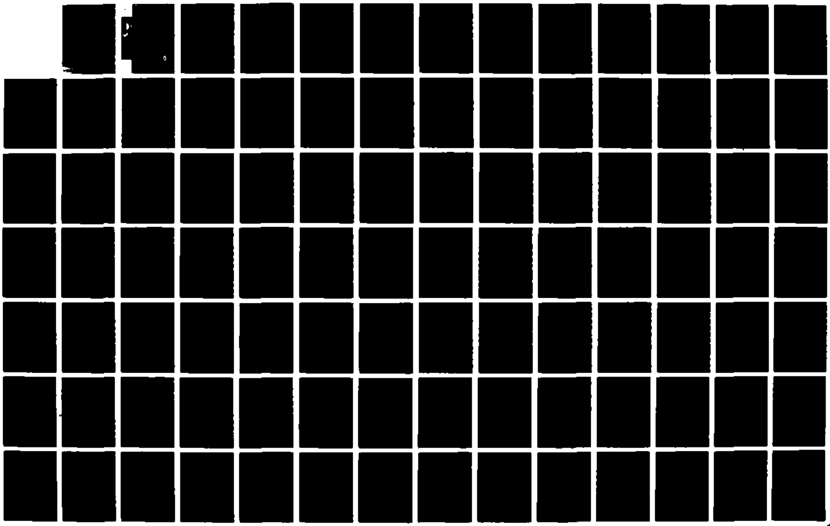

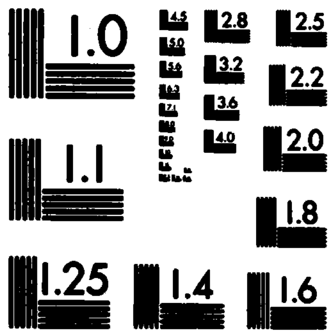

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FINE-GRAINED SEDIMENTS AN ANNOTATED BIBLIOGRAPHY ON THEIR DYNAMIC BEHAVIOR IN AQUATIC SYSTEMS

by

A. Teeter, S. Hodges, C. Coleman

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
PO Box 631, Vicksburg, Mississippi 39180-0631

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This bibliography compiled annotated citations on consolidation, deposition, engineering works, erosion, field studies, hydrodynamics, modeling, sediment properties, study methods, and transport aspects of fine-grained sediment behavior in aquatic systems.
Keywords: Aquatic sediments, Sediment transport.

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FINE-GRAINED SEDIMENTS: AN ANNOTATED BIBLIOGRAPHY ON THEIR DYNAMIC BEHAVIOR IN AQUATIC SYSTEMS

PART I: INTRODUCTION

1. The US Army Corps of Engineers spends in excess of $250 million per year on the dredging of navigation channels, of which more than half is required for coastal area dredging. A large part of the material being dredged consists of fine-grained sediments whose behavior is poorly understood. Sediment dynamics are magnified and more difficult to analyze in areas of unsteady flows and changing water chemistry such as in estuaries.

2. Fine-grained sediment dynamics play an important role in the fate and transport of many pollutants which sorb to sediment surfaces.

3. The purpose of this bibliography was to aid in understanding the behavior of fine-grained sediments by providing a starting-point reference for specific fine-grained sediment studies. Fine-grained sediments have been studied by hydraulic engineers, chemical engineers, geologists, environmental engineers, oceanographers, limnologists, and physicists. For this reason, the literature on fine-grained sediments is scattered in the journals of a number of disciplines. The literature on specific fine-grained sediment topics can be scarce and difficult to find. Therefore, the objective of this bibliography was to draw together enough breadth and depth of the various literature sources on fine-grained sediments to serve as a general reference. The bibliography can also provide a means of identifying information gaps and the consistencies between different theories or between theories and observations.

4. Any bibliography becomes out-of-date at a rate proportional to the amount of new material which is published. This bibliography was published in such a way that it could be updated if circumstances warrant. For this reason, references in the main body of the bibliography were printed one to a page. Subject and keyword lists, presented in the following parts, were computerized to facilitate future detailed searches and improvements in subject coverage.

PART II: DEVELOPMENT OF THE BIBLIOGRAPHY

5. The main body of the bibliography (Part IV) consists of reference citations and annotations. The annotations were drawn from the author-prepared abstracts of the works or were abstracted from the works. The annotations are descriptive or informative or both. The criteria for selection of references included in the bibliography included the following:

   a. Pertains to some aspect of fine-grained sediments.

   b. Describes some technique or property that is shared with fine-grained sediments.

   c. Is available in the open literature.

6. During the assembly of the bibliography, ten general subjects were identified. Keywords were identified for each citation. A list of the ten subject headings and the keywords associated with each subject follows:

Subject	Keywords
Consolidation	Floc settling
	Self-weight consolidation
	Hindered settling consolidation
	Compaction
	Finite strain theory
	Pore-water pressure
	Thixotrophy
	Particle interactions
Deposition	Critical shear stress
	Sedimentation
	Mud
	Tidal deposits
	Bed flux
	Siltation
	Fluid Mud
	Shoaling
	Deposition rate
Engineering works	Waste discharges
	Dredged channel
	Training works
	Harbors
	Piers and wharves
	Settling basins
	Sediment traps
	Reservoirs
	Drops

(Continued)

PREFACE

This bibliography presents work performed under the Improvement of Operations and Maintenance Techniques (IOMT) Research Program by the Hydraulics Laboratory (HL) of the US Army Engineer Waterways Experiment Station (WES). The IOMT Research Program is sponsored by the Office, Chief of Engineers, US Army. The IOMT work unit under which this bibliography was produced is entitled "Fine-Grained Shoaling in Navigation Channels" (Work Unit No. 31765). The objective of this research work unit is to define the dynamic behavior of fine-grained sediments so that navigation channel shoaling can be predicted more accurately and more effective remedies can be designed.

Work was performed under the general supervision of Messrs. F. A. Herrmann, Jr., Chief, HL; R. A. Sager, Assistant Chief, HL, and former Chief of the Estuaries Division (ED); W. H. McAnally, Chief, ED, and initial project engineer; E. C. McNair, former Chief, Sedimentation Branch, and former project engineer; and A. M. Teeter, ED, current project engineer. Ms. S. Hodges, ED, acquired and compiled the material for this bibliography. Ms. C. Coleman, ED, edited and organized the citations.

COL Allen F. Grum, USA, was the previous Director of WES. COL Dwayne G. Lee, CE, is the present Commander and Director. Dr. Robert W. Whalin is Technical Director.

CONTENTS

Subject	Keywords
Engineering works (Continued)	Channel enlargement Dredging Locks
Erosion	Critical shear stress Eroding fluid Surface erosion Sheet erosion Mass erosion Particle erosion Erosion rates Glacial grinding Weathering Resuspension potential Hydraulic shear strength
Field studies	Boat waves Tidal rivers Estuaries Tidal flows Currents Velocities Mixing Shelf waves Sediment concentration Salinity distribution Friction coefficient Stratification Circulation Longitudinal dispersion Lateral dispersion Deltas Mud ridges Shoals Turbidity maximums Marine clays Mineralogy Morphology Tidal inlets Coastal Stratigraphy Water quality Spring-neap effect Subtidal effect
Hydrodynamics	Velocity profile Turbulence Channel flow Friction Stress development

(Continued)

Subject	Keywords
Hydrodynamics (Continued)	Stratified flow
	Salt wedge
	Unsteady flow
	Vertical transport
	Waves
	Normal stresses
	Shear stresses
	Buoyancy effects
	Dispersive transport
	Viscosity
Modeling	Hydraulic model
	Laboratory model
	Predictive equation
	Statistical model
	Theoretical model
	Mathematical model
	Numerical model
	Mixing model
	Source and sink functions
	Information base
	Turbulence model
	Transport model
	Vertically averaged
	Laterally averaged
	Finite difference
	Finite element
	One-dimensional
	Three-dimensional
Sediment properties	Silts
	Clays
	Cohesion
	Particle size
	Particle shape
	Aggregation
	Flocculation
	Particle dispersion
	Deflocculation
	Coagulation
	Disassociation
	Physicochemical properties
	Adsorption
	Water quality
	Particle bonding
	Pair forming
	Rheological properties
	Bulk densities
	Settled densities
	Electromagnetic properties
	Pore fluid

(Continued)

Subject	Keywords
Study methods	Water samplers Sediment samplers Bed-load samplers Acoustic detection Optical measurement Density measurement Data collection Data quality control Tracer techniques Dating techniques Characterization tests Statistical analyses Velocity measurements Shear stress measurements Concentration measurements Particle size measurements Settling velocity measurements Error analysis
Transport	Turbidity currents Suspended transport Saltation Bed-load transport Fluid mud Mobile dense suspensions Diffusion coefficients Exchange coefficients Residence times Purging rates Variability Secondary currents Net transport Dead zones

7. A subject index assigning each entry to one of the ten subject headings is presented in Part III.

PART III: SUBJECT INDEX

Subject: Consolidation

Subject: Deposition

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PART IV: REFERENCE LISTINGS AND ANNOTATIONS

A

AGNEW, H. J., BILLINGS, J., and IMBERGER, J. 1975. "Sediment Transport Processes in the Blackwood River Estuary, Western Australia," The Engineer, the Coast, and The Ocean, Second Australian Conference on Coastal and Ocean Engineering, Gold Coast, Queensland, Australia, 27 Apr-1 May 1975.

Velocity and dispersion characteristics were determined, by current metering and aerial photography of dye, for winter flow conditions in the Blackwood River estuary, Western Australia. The implications of these results were discussed with regard to the distribution of sediment likely to result from a proposed dredge mining operation.

AITCHISON, J., and BROWN, J. A. C. 1957. "The Lognormal Distribution," Monograph No. 5, University of Cambridge, Department of Applied Economics, Cambridge, England.

The lognormal distribution in its simplest form may be defined as the distribution of a variate whose logarithm obeys the normal law of probability. Under a variety of names--the Galton-McAlister, Kapteyn, Gibrat, the logarithmico-normal, or simply the lognormal distribution--it has had a long, though at times precarious, career in the theory and application of statistics. Its literature is large but diffuse, and the first intention was merely to undertake a collation which was long overdue. It soon appeared, however, that there remained some unexplored problems and that some valuable properties of the distribution had been either overlooked or inadequately exploited. For those who are already familiar with the distribution, it is hoped that this monograph will prove a useful work of reference. It is hoped that the efforts may establish the distribution as a powerful tool for those less acquainted with its possibilities.

Many examples of the lognormal distribution have been noted in nature from a variety of fields ranging from sedimentary petrology to the analysis of literary style. Although the authors' interest in the subject derives mainly from its use in the analysis of economic data, a number of other applications are discussed in Chapter 10 as they are recorded in the literature. The discussion of problems of more particular interest to the economist is contained in Chapter 11, where they deal with the statistical analysis of income distributions and measures of the concentration of income, and in Chapter 12, where they consider applications to econometric models of consumer demand. In the remaining chapters, which are concerned with general properties and estimation procedures, a bias towards any particular branch of science is avoided. It is hoped that the bibliography which is appended is sufficiently complete to provide a point of departure for the reader interested in a particular field.

ALBONE, E. S., EGLINTON, G., EVANS, N. C., HUNTER, J. M., and RHEAD, M. M. 1972. "Fate of DDT in Severn Estuary Sediments," Environmental Science and Technology, Vol 6, No. 10, pp 914-919.

The functions of estuarine sediments as pollutant sink and as pollutant bank are assessed in relation to the fate of DDT in the environment. p,p'-DDT was degraded more slowly when incorporated in situ in Severn estuary sediments than when incubated in sediment samples maintained under hydrogen in the laboratory. These transformations are compared with the more extensive degradation of DDT on incubation in anaerobic sewage sludge. In all incubation, metabolites included p,p'-DDT. The wider application of the techniques developed is discussed.

ALLEN, G. P., BONNEFILLE, R., COURTOIS, G., and MIGNIOT, C. 1974. "Sedimentary Processes of the Mud in the Gironde Estuary: Contribution of a Radioactive Tracer to the Study of Mud Displacements" ("Processus de transport et d'accumulation des sediments dans l'estuaire de la Gironde. Contribution d'un traceur radioactif pour l'etude du deplacement des vases"), La Houille Blanche, Vol 29, No. 1/2, pp 129-136.

The hydraulic and sedimentological processes operating in the Gironde estuary (southwest France) are linked to the interaction between the river discharge (mean values between 800 and 1,000 cu m/sec), tides (ranges from 2 to 6 m), the suspended sediment influx from the rivers (2 to 3 million tons per year), and the general morphology of the estuary, consisting in two channel systems separated by a series of islets, shoals, and bars.

The deposition of suspended sediment in the main estuarine channel occurs through the formation of pools of extremely turbid bottom water (100-300 g/ℓ). Practically no movement is discernible in these pools of "fluid mud" and intense bottom deposition by settling occurs. These pools are formed in the core of the turbidity maximum. Zones of "motionless lenses" on the bottom occur at flood slack by the velocity-time asymmetry.

This fluid mud follows a cycle of erosion and deposition linked to the monthly cycle in tidal ranges. During neap tides the mud accumulates, and during spring tides it is eroded and resuspended into the overlying turbidity maximum.

Based on suspended sediment flux measurements in the lower estuary and analysis of the plume of turbid estuarial water escaping onto the continental shelf during river floods and spring tides, it appears that a significant amount of alluvial suspended sediment bypasses the estuary and is deposited in a silt and clay zone on the inner continental shelf. Possibly part of this estuarine water is recirculated in an estuarine and lagoonal system further north.

In order to study and assess the diffusion of the fluid mud into the turbidity maximum during spring tides, and also to follow the upstream migration of these fluid mud pools during a period of decreasing river discharge, a radioactive tracer study was made of the fluid mud. This study showed that a very slow movement on the order of 0.1-0.2 cm occurs in the fluid mud and appears to be directed downstream. Also it was shown that at each cycle of erosion and deposition of the fluid mud, which reformed further upstream at each cycle, the same sediment appears to be recycled.

ALLEN, G. P., SALOMON, J. C., BASSOULLET, P., DuPENHOAT, Y., and DeGRANDPRE, C. 1980. "Effects of Tides on Mixing and Suspended Sediment Transport in Macrotidal Estuaries," Sedimentary Geology, Vol 26, No. 1/3, pp 69-90.

Studies in estuaries on the French Atlantic coast, with tides ranging from 4 to 7 m, have shown that in macrotidal estuaries, semidiurnal and fortnightly tidal cycles play a significant role in controlling hydrological and sedimentological processes.

During the fortnightly neap-spring cycle of tidal amplitudes, the tidal prism varies considerably, bringing about significant changes in the ratio of river flow to tidal volume. This in turn causes large variations in mixing, and the estuaries can change from a relatively well-mixed state during spring tides to partially mixed or even well stratified during neap tides. The changes in the tidal-averaged water volume of the estuaries during the neap-spring sequence induce a residual accumulation of water in the estuary during increasing tide range and a residual seaward discharge during decreasing tide range. This purely tidal effect can probably influence the flow of fresh water and suspended sediment seaward from the estuary.

During every semidiurnal tidal cycle, large amounts of fine sediment are alternately eroded, resuspended, and deposited, and the turbidity maximum in these estuaries appears as essentially a tide-induced phenomenon. Upstream transport of suspended sediment caused by the ebb-flow asymmetry of the shoaling tidal wave appears to create a tidal sediment trap in the upper estuary, even in the absence of density circulation.

Neap-spring tide cycles control sedimentation and seaward escape of suspended sediment. Large-scale erosion and resuspension occur during spring tides, increasing the residence time of fine sediment in the aquatic environment and providing a mechanism for enhancing seaward escape of suspended sediment.

In hypersynchronous estuaries, where tidal damping by friction is less than the effect of the upstream convergence, tidal amplitude and power dissipation can attain a maximum within the estuary. Numerical simulation of suspended sediment in the Gironde estuary shows that this process also contributes to the formation of the turbidity maximum.

ALLEN, G. P., SAUZAY, G., CASTAING, P., and JOUANNEAU, J. M. 1976. "Transport and Deposition of Suspended Sediment in the Gironde Estuary, France," Estuarine Processes, M. Wiley, ed., Vol II, pp 63-81, Academic Press, New York.

A highly concentrated (1-10 g/ℓ) turbidity maximum develops at the upstream limit of the salinity intrusion in the Gironde estuary, nourished by the large seasonal influx of alluvial suspended sediment.

The estuary contains two distinct channel systems. In the deeper southern channel, a marked tidal cycle occurs: during neap tides, fluid mud accumulates from settling in the core of the turbidity maximum; during spring tides it is eroded and resuspended. The turbidity maximum and fluid mud undergo a seasonal upstream-downstream migration in response to varying river discharge.

These phenomena have been studied using hydrological and radioactive tracer techniques. Very little movement and diffusion occur within the fluid mud. At each cycle of accumulation and resuspension, a residual lamination is deposited in the channel. During high river flow, the resuspended mud is transported by lateral advection to the north channel, where part settles out and part is evacuated out to sea. This lateral migration and seaward escape appears to be amplified by dredging.

Sediment renewal in the fluid mud-turbidity maximum system appears to be related to its position in the estuary. Downstream, lateral losses induce a rapid turnover; upstream, it behaves more like a closed system, with internal recycling.

ALLERSMA, E. 1980a. "Additional Remarks on the Collection of Data," International Symposium on River Sedimentation, Chinese Society of Hydraulic Engineering, Beijing, China, pp 1285-1289.

The real picture of an actual siltation can be obtained only from observation in nature. This paper provides remarks on the collection of data.

ALLERSMA, E. 1980b. "Mud in Estuaries and Along Coasts," International Symposium on River Sedimentation, Chinese Society of Hydraulic Engineering, Beijing, China, pp 663-685.

Mud plays an important role in morphological processes in many estuaries and along certain coasts. The properties of cohesive sediments combine with the hydraulic phenomena in these waters to form complex transport patterns. As estuaries are the scene of many civil engineering works, estuarine sediment transport patterns are the subject of many studies. The hydraulic phenomena in estuaries and along coasts are a continuously varying interaction between the discharge (fresh water) of a river, the intrusion of salt water from the sea, tidal oscillations, ocean currents, and waves, often in a complex geometry.

Mud forms a bottom of which cohesion is a characteristic property caused by a high content of clay minerals. These fine sediments show their own behavior in the aquatic environment during erosion, transport, and deposition. They are easily suspended in water, and these suspensions of various concentrations play an important role in transport processes. The transport of mud in estuaries shows variations with periods of the waves, the tides, the fortnightly spring/neap cycles, and the hydrologic seasons, as well as with the location in the area. Observation of these phenomena to provide some basic understanding is a major effort.

Along muddy coasts, transports are caused mainly by the eroding waves and transporting currents, also variable. Fluid mud plays an important role in the process of deposition. The morphology of the coast may include large periodic features as observed along the coast of Guyana.

Prediction of deepening and shoaling, estimation of maintenance dredging, and forecasting of the erosion and accretion of a coast to be defended are examples of technical problems requiring studies of the complex transport phenomena of mud. The large specific surface and the electrochemical activity of clay particles lead to the adsorption of a great number of chemicals, natural as well as artificial. Differences in the natural composition can be used as tracers for the movements of the sediment. For the same purpose, markers (radioactive, radioactivable, or stable) can be attached to the sediment. A more recent development is the use of the natural ration of stable isotopes as a characteristic property. Another category of artificial absorbents stems from pollution. Large quantities of these polluted sediments are deposited in estuaries and coastal waters, remaining a threat to the environment into the distant future.

ALLERSMA, E., HOEKSTRA, A. J., and BIJKER, E. W. 1967. "Transport Patterns in the Chao Phya Estuary," Publication No. 47, pp 632-650, Delft Hydraulics Laboratory, Delft, The Netherlands.

Present-day society asks for ever larger engineering works to be carried out in estuaries. The developing techniques of dredging and construction allow for great interventions in the natural phenomena with often far-reaching consequences. The whole intricate system of transports of water, salt, and sediments may be drastically changed, affecting the existing quasi-static equilibria between sedimentation and erosion. For the planning of such works, a thorough knowledge of the estuarine hydrology is indispensable.

The Netherlands Engineering Consultants (NEDECO) in combination with the Delft Hydraulics Laboratory have made a 4-year study of the estuary covering a field survey and a hydraulic model test. The observations in nature served to obtain insight into the estuarine transport pattern in relation with the boundary conditions given by the regimen of the river and the state of the sea. The small-scale tests gave indications of the changes in these phenomena to be expected from alterations of the situation in the estuary and of the discharge characteristics of the river.

The field survey was carried out from 1961 to 1963 with four fully equipped survey vessels to measure current velocities (60,000 times), to take samples of water and sediments, to measure wave heights, and to take echo soundings. In a laboratory, the samples of water (70,000) and sediments were tested for silt concentration, salinity, and soil mechanical properties. Together with meteorological, oceanographical, and hydrological data from cooperating local authorities, a picture was obtained of the phenomena in the estuary and the causes of the siltation in the dredged channel.

The model comprised the 160-km-long estuarine stretch of the Chao Phya and the adjacent 20- by 40-sq km part of the Gulf of Thailand in which the river has deposited vast mud flats through which the navigation channel has been dredged. The scale of the horizontal dimensions was 1:500 while the depths were on a scale of 1:100. The seaward boundary was provided with a tide generator and a supply of salt water which, together with the fresh discharge of the river, gave a good simulation of the hydraulic phenomena in the estuary. Tests with other situations gave indications of the changes in the hydraulic phenomena which, in turn, could be translated into changes of the silting pattern via relationships derived from the data of the field survey.

AMANO, R., and HAMADA, T. 1957. "Siltation in Estuary and Coastal Water," XIXth International Navigation Congress, London, England, Paper S.II-C.3, pp 157-174.

In this paper, the observation of littoral drift at a depth of 6 m is explained. In other observations of various depths, similar results were obtained, which were indicative of the accurate properties of drifting sand. This modern method by radioisotope can be used for the tracing of siltation and sand drift problems in estuarial and coastal waters. Of course, this method must be applied with the careful consideration of many other factors, i.e., waves, winds, tides, storm surges, floods, and topographical characteristics, etc.

In this experiment ^{65}ZN has been used as a radioactive isotope, but in conformity with the purpose and method of experiment, many kinds of radioisotope should be used. For the observation of long duration, the utilization of ^{60}CO (half life of 5.3 yr, gamma-ray 1.115 - 1.317 Mev) may be suitable, and for the problem of short period the application of ^{46}SC (half life of 85 days, gamma-ray 0.89 - 1.12 Mev) may be useful. At the observation of drift of the industrial port of Tomakomai, ^{60}CO is used since this year.

The Port and Harbour Bureau of the Japanese Government intended to apply the radioisotope extensively in 1957 as a tracer of coastal and estuarial siltations of many Japanese ports.

ANDERSON, F. E. 1974. "The Effect of Boat Waves on the Sedimentary Processes of a New England Tidal Flat," Government Reports Announcements AD-774 902, Vol 74, No. 9.

In order to estimate the effect of increased boat traffic on channel bank and tidal flat erosion, a system of intake values was "plumbed" into a portion of a tidal flat in the Great Bay Estuary of New Hampshire. Waves were set up from six different boats, ranging in size from 13 to 34 ft. Water samples were collected from eight stations orthogonally spaced over the tidal flat. At each station, water samples at 30 and 15 cm off the bottom were collected before, during, and after the boat wave passed by and were filtered for total suspended load. The boat wave characteristics were measured, along with the bottom currents, salinity, near bottom temperatures, and temperature profiles of the water column. Boat waves were set up at the beginning of the flood phase and near the end of the ebb. These waves were set up at the same water depth for each phase of the tide.

The study indicates that the boat waves can resuspend one-third to one-half more sediments under the same wave conditions on the flood tide than on the ebb tide. In this case, during the flood tide the resuspended sediments were transported seaward in a tidal current gyre in the sampling area. There is a possibility that density underflows may form under severe wave activity and cause additional seaward transportation.

The horizontal bottom velocities, calculated from the boat wave characteristics as low as 15 cm/sec, were able to resuspend fine-grained estuarine sediments.

ANDERSON, F. E. 1976. "Rapid Settling Rates Observed in Sediments Resuspended by Boat Waves Over a Tidal Flat," Netherlands Journal of Sea Research, Vol 10, No. 1, pp 44-58.

A series of boat waves were directed across the tidal flat at varying water depths to (a) compare the different amounts of wave energy expended in each area of the tidal flat and (b) examine the post-boat wave effects on sediment resuspension and deposition.

More of the boat wave energy appears to be expended on the outer portion of the tidal flat (near low-tide mark) than the inner portion when comparable water depths are observed. This observation coupled with the fact that the low-tide area is under water for more of the tidal cycle than the upper tidal zone indicates that a decreasing energy gradient exists across the tidal flat. Because of this energy gradient, the outer portion of the tidal flat appears to be the most dynamic with alternate periods of resuspension and deposition. In contrast, the inner area is primarily depositional.

Near the low-tide mark, sediments are easily resuspended, yet just as easily deposited. Their apparent high deposition rates are anomalous for the bottom sediment texture (pipette analysis) of the area, and it is inferred the sediment particles are behaving more like low-density aggregates rather than individual grains of silt or clay. The source of these aggregates may be local pelletization by benthic fauna or physical aggregation caused by reworking of the bottom sediments by waves.

ANONYMOUS. 1978 (Sep). "Port of Bristol: Silt-Laden Tidewaters Create Dredging Need in Impounded Dock Systems," World Dredging and Marine Construction, Vol 14, No. 9, pp 60-62.

The Port of Bristol Authority maintains and operates three impounded dock systems adjacent to the point where the river Avon joins the Severn estuary. At the entrance to the city docks, silt-laden tidewater makes its way in through the locks, particularly when spring tides flow higher than the maintaining level of the docks. High spring tides also force open the gates in the river mouth docks and bring tidewater directly into the impounded docks.

Siltation, occurring in the impounded areas of the lock pits and entrance piers, creates a dredging need. The Royal Portbury Dock's dredging operations are based on regular hydrographic surveys. They employ a suction trailer, triple grab, bucket dredge, and cutter section as a fleet and maintain relatively low maintenance cost.

ANWAR, H. O., and ATKINS, R. 1980 (Aug). "Turbulence Measurements in Simulated Tidal Flow," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 106, No. HY8, pp 1273-1289.

The dispersion and transport of dissolved pollutants by turbulence in flowing water have emphasized the need to undertake more detailed measurements for a better understanding of the structure of turbulent flow, especially when the current is subject to tidal variations. It is indicated that the unsteady phases of a tidal stream have a strong effect on the mechanism of turbulence, and thus the classical methods of predicting the turbulent parameters, based on steady flow, are in error. The paper studies the effects induced by the temporal variations in the velocity field on the turbulence characteristics of unsteady flows under more closely controlled conditions.

APRIL, G. C., NG, S., LIU, H.-A., and HILL, D. O. 1976 (Jan). "Predicting Material Transportation in Mobile Bay," Proceedings of the Specialty Conference on Dredging and Its Environmental Effects, American Society of Civil Engineers, 26-28 Jan 1976, pp 833-855.

Models for the prediction of hydrodynamic, salinity, coliform bacteria, and sediment behavior have been developed for Mobile Bay. These models allow for (a) variability in grid size to obtain the desired detail in water-land boundaries, dynamic boundaries, and other points of interest within the system; (b) the effects of the earth's rotation; (c) effects of rapidly changing velocities; (d) the variability in bottom friction; (e) resistance created by dredged material banks; (f) variability in freshwater flow; (g) effects of wind conditions; (h) effects of the salinity wedge; (i) variability in the total coliform source concentration at several locations; (j) variability in water temperature as related to coliform bacteria die-off rate constants; and (k) long- and short-range sediment transport and deposition trends. These paradigms are based on established engineering practice and available data sources and constitute the necessary framework for the development of other models and data collection programs in support of projects related to water quality and water resource assessment.

ARIATHURAI, R. 1974 (Aug). "A Finite Element Model for Sediment Transport in Estuaries," Ph.D Dissertation, University of California, Davis, Department of Civil Engineering, Davis, Calif.

The prime objective of this study was to develop a mathematical model for sediment transport in estuaries. This has been achieved. The versatile finite element method has been used to effect a stable solution of the convection-diffusion equation in the two horizontal dimensions. With minor modifications, the program may be used for the vertical and axial dimensions that are more appropriate in rivers and narrow estuaries.

The model utilizes the relations developed for depositions and for erosion. In addition, the fact that fresh deposits are susceptible to mass erosion is used. Continuing aggregation is accounted for by specifying appropriate settling velocities in each element for each time stop. A table of salinities at which each of the three main clay types becomes cohesive has been presented. This is useful in predicting potential aggregation as suspended sediments move from fresh to saline waters.

The accuracy with which the model predicts sediment concentrations and bed profiles depends primarily on the accuracy of the current velocities and sediment properties that are used.

ARIATHURAI, R., and ARULANANDAN, K. 1978 (Feb). "Erosion Rates of Cohesive Soils," Technical Notes, Journal, Hydraulics Division, American Society of Civil Engineers, Vol 104, No. HY2, pp 279-283.

The results of erosion tests on over 200 natural and made-up soil samples indicate that the erosion rate constant M lies in the range 0.003 g/sq cm/min-0.03 g/sq cm/min with few exceptions. The slope s of the erosion rate curves increases with increase in critical shear stress (τ_c). If the relationship between s and τ_c were inverse, then $M = s\tau_c$ would be independent of the critical shear stress although M may vary with other chemical and physical parameters. If further measurements designed to investigate the relationship between the erodibility constants τ_c and M should yield a functional relationship between the two, there will be one less parameter to deal with in problems such as the determination of soil yield from watersheds and estuarial sediment transport.

ARIATHURAI, R., and KRONE, R. B. 1976a (Mar). "Finite Element Model for Cohesive Sediment Transport," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 102, No. HY3, pp 323-338.

Estuaries are zones of transition from unidirectional freshwater flows of land drainage to a tidal saline ocean. Water movements in estuaries are constantly varying free surface flows of water having varying density. Wave motions are often superimposed on the flows. Sediment circulations are even more complex than those of ocean waters. Sediments transported by estuaries typically contain large portions of clay and silt materials which, in the saline waters and hydraulic conditions of the estuary, may aggregate and settle in regions of low flow intensity. The mechanism of scour, transport, and deposition of cohesive sediments is different from the transport of noncohesive sediments, which are principally transported as discrete particles having constant density and dimensions.

The effects of sediments on water quality for aquatic biota include limitation of the penetration of sunlight and the sorption and exchange of ions from solution. Cohesive sediments provide a large assimilative capacity for heavy metals, pesticides, and nutrients discharged to the waters in wastes. The process of sorption may be followed by exchange of some of the ions in a saline environment and subsequent deposition.

Maintenance of navigable waterways, the control of estuarine water pollution, and the preservation of the balance of the aquatic ecosystem, all of which are affected by the sediment circulations in the estuary, have been problems of considerable concern to those responsible for the management of estuaries. The mathematical model described herein was developed with these needs in mind. It was designed to describe the concentrations of suspended sediments and the bed surface elevations as they vary with time.

ARIATHURAI, R., and KRONE, R. B. 1976b. "Mathematical Modeling of Sediment Transport in Estuaries," Estuarine Processes, M. Wiley, ed., Vol II, pp 98-106, Academic Press, New York.

The elements to be considered in a mathematical model for estuarial sediment transport are presented. These elements include convection-diffusion terms and source and sink functions based on previous laboratory experiments. The experimental results yielded descriptions of deposition from suspension and erosion of cohesive beds.

Mathematical models that simulate the transport of cohesive sediments are reviewed with recommendations for future work.

ARIATHURAI, R., and MEHTA, A. J. 1983 (Mar). "Fine Sediments in Waterway and Harbor Shoaling Problems," International Conference on Coastal and Port Engineering in Developing Countries, Colombo, Sri Lanka, 20-26 Mar 1983, pp 1094-1108.

Fine, cohesive sediment transport and deposition in waterways and harbors often lead to shoaling problems of critical economic significance. There is the associated problem of the accumulation of sorbed toxicants and resultant degradation of water quality. Quantitative relationships describing the various fine sediment transport processes including erosion and deposition are available. The investigation of any particular problem requires careful field monitoring as well as laboratory tests for characterizing basic properties of the sediment in suspension and the bed. While in some cases simple sediment budget computations will suffice, accurate simulation of shoaling patterns and estimation of the rates of shoaling require the use of mathematical models. Such models have been used in numerous applications.

ARIATHURAI, R., MacARTHUR, R. C., and KRONE, R. B., 1977 (Oct). "Mathematical Model of Estuarial Sediment Transport," Technical Report D-77-12, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A two-dimensional finite element model that simulates erosion, transport, and deposition of suspended sediments is presented. The breadth-averaged or depth-averaged equations may be used depending on the problem to be solved. The governing equations for two-phase transport are derived and then solved by the finite element method using isoparametric quadrilateral elements in which a quadratic approximation is made for the suspended sediment concentrations.

Expressions used for the rates and conditions under which erosion and deposition occur are from previous experimental studies. Continuing aggregation is accounted for by specifying the settling velocity of the flocs in each element at each time step. The bed is considered to be formed of a number of layers of sediment whose physical properties change with overburden pressure. The model provides suspended sediment concentrations and bed profile at each time step.

Numerical stability and convergence tests were conducted by comparing simulated results with analytic solutions and actual measurements. The original model, SEDIMENT I, was verified by comparison with measurements in a recirculating flume. The modified model, SEDIMENT II, developed for this project was verified by comparison with field measurements in the Savannah estuary, Georgia.

ARULANANDAN, K. 1975 (May). "Fundamental Aspects of Erosion of Cohesive Soils," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 101, No. HY5, pp 635-639.

The influence of soil systems at different dispersed rates on the erodibility and swelling is well demonstrated. The degree of dispersion of the soil is influenced by mineralogy, amount of clay, sodium adsorption ratio (SAR), concentration of pore fluids, and the differences in the concentration between the pore and eroding fluids have to be considered in evaluating the erosion potentials of soils.

For prediction of erodibility, a tentative relationship between cation exchange capacity (a value which varies with or depends on the type of clay) and critical shear stress at a particular concentration of pore fluid at low and high values of SAR is presented.

Experimental and theoretical investigation of erosion is in progress to obtain a functional relationship between structural parameters quantified in terms of electrical properties and erodibility.

ARULANANDAN, K., GILLOGLEY, E., and TULLY, R. 1980 (Jul). "Development of a Quantitative Method to Predict Critical Shear Stress and Rate of Erosion of Natural Undisturbed Cohesive Soils," Technical Report GL-80-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This study was conducted in an attempt to develop a quantitative method to predict the hydraulic shear stress at which erosion is initiated (critical shear stress) and the rate of erosion of natural soil (with sufficient cohesiveness to allow undisturbed samples to be taken) along the streambank. In order to obtain a wide range of properties with sufficient geographical distribution, soil and river water samples were requested from US Army Corps of Engineers (CE) Districts in the United States. Based upon the results of preliminary tests, 30 soils were selected for detailed analysis which included (a) index property tests (hydrometer analyses, specific gravity, organic content, gypsum content, moisture content, unit weight, and Atterberg limits); (b) soil chemistry (exchangeable cations); (c) dielectric dispersion on undisturbed soil; (d) flume erosion tests on undisturbed soil; and (e) rotating cylinder erosion tests on saturated remolded soil.

The results of the study showed that remolding the soil generally decreased both the critical shear stress and the rate of change of erosion rate. The salt concentration of the eroding fluid significantly influenced the erosion of remolded soil samples. Usually, as the salt concentration of the river (eroding) water decreased, the critical shear stress of the soil decreased, and the rate of change of erosion rate increased.

The results of the study did not yield a quantitative method to predict critical shear stress and/or rate of erosion for undisturbed natural soils. However, it was shown that a previously developed chart for remolded soil gave a predicted value of critical shear stress that was generally less than the measured value for undisturbed soil using distilled water as eroding fluid.

ARULANANDAN, K., LOGANATHAN, P., and KRONE, R. B. 1975 (Jan). "Pore and Eroding Fluid Influences on Surface Erosion of Soil," Journal, Geotechnical Engineering Division, American Society of Civil Engineers, Vol 100, No. GT1, pp 51-66.

This paper has three objectives: (a) a review of the literature concerning the extent of flocculation of clays; (b) a method to measure the shear stress T_c required to initiate erosion; and (c) data to show the influences of pore and eroding fluid compositions on the shear stress required to initiate erosion, and to examine the influence of pore fluid composition on the swellability of clay in order to explain the mechanism causing erosion.

ASHLEY, G. M., SOUTHARD, J. B., and BOOTHROYD, J. C. 1982 (Feb). "Deposition of Climbing-ripple Beds: A Flume Simulation," Sedimentology, Vol 29, No. 1, pp 67-79.

Thirteen runs were made in a small recirculating flume to simulate the deposition of the climbing-ripple sequences commonly present in fine-grained facies of fluvial and deltaic deposits. These sequences consist of intergradational climbing-ripple cross-laminae and draped laminae. The experiments were based on the assumption that stratification type depends mainly on near-bottom flow structure and uniform sediment fallout from an overloaded flow. Various combinations of curves of velocity versus time and of sediment feed versus time in runs lasting from 45 to 840 min were used in an exploratory program; conditions for each run were selected on the basis of experience in previous runs. The runs verified that Type A (erosional-stoss) climbing ripples are produced by aggradation rates that are small relative to ripple migration rate, and Type B (depositional-stoss) climbing ripples are produced by aggradation rates that are large relative to ripple migration rate. Draped lamination results from continued fallout of sediment from suspension after ripple migration ceases or almost ceases. Comparison of geometric details of the ripple stratification produced in the flume runs with that in natural sequences, supplemented by considerations on maximum and minimum migration rates of ripples, suggests times of no more than a few tens of hours for the deposition of the climbing-ripple portions of sequences 10-20 cm thick. Runs in which deposition of a 20-cm sequence took more than 10 hours produced such atypical features of ripple geometry as sharp crests, planar lee-side laminae, and angular toeset-foreset contacts.

ASKREN, D. R. 1979 (Aug). "Simulated Circulation and Sedimentation in Marinas," Proceedings of the Specialty Conference on Conservation and Utilization of Water and Energy Resources, American Society of Civil Engineers, San Francisco, 8-11 Aug 1979, pp 305-314.

This study has considered the phenomena of shear-driven vortex circulation and sedimentation in rectangular basins connected to a waterway. From the consideration of the dependence of these phenomena on basin and environmental parameters, the following design recommendations are given.

A basin length/width (L/W) ratio greater than unity should be used to optimize the balance between basin-averaged sedimentation rates and velocities. In no case should the L/W ratio be less than about 0.3 or greater than about 2.0 since undesirable secondary vortices form in the basin interior and adversely affect basin circulation.

Where single entrances are used, the entrance should be centrally positioned in the breakwater if the adjacent channel lacks significant suspended sediment concentrations. This will maximize velocities within the basin.

Where sedimentation in the basin is expected to be a problem and a single entrance is to be used, the entrance should be displaced some distance upstream or downstream of the center of the breakwater. The amount of displacement will depend on the concentration of suspended sediments and on the channel velocity.

Multiple entrances are desirable since they provide an opportunity to develop a through-flowing current.

The parameter r_x/L, where r_x is the distance between the vortex center and the maximum velocity component v_m acting perpendicular to the channel, is a convenient measure of momentum transfer and circulation efficiency. Maximizing r_x/L should minimize the number of circulation cells present and maximize the momentum exchange between basin and exterior waters.

B

BALLINGER, D. G., and McKEE, G. D. 1971 (Feb). "Chemical Characterization of Bottom Sediments," Journal Water Pollution Control Federation, Vol 43, No. 2, pp 216-227.

The characterization of bottom sediments, while an important consideration in water pollution studies, depends on subjective observation of color, odor, texture, and stream location. Through the use of routine chemical oxygen demand and Kjeldahl nitrogen tests, a system of sediment analysis has been developed to yield objective information that may be specifically correlated to source of deposit and probable influence on overlying water. Laboratory examination of more than 200 sediment samples from a variety of streams, lakes, and estuaries was used to classify bottom deposits into four general types on the basis of percentages of organic carbon and nitrogen. The product of the percentages was used as an index of the organic nature of the sediment (OSI). The correlation of OSI with stream loading and flow characteristics was demonstrated.

BARENBLATT, G. I. 1953. "On the Motion of Suspended Particles in a Turbulent Stream," Prikladnaya Mathematika Mekhanika, Vol 17, No. 3, pp 261-274.

In the work, conclusions are given on the general equation for the turbulent flow of nonhomogeneous liquids, i.e., liquids containing suspended particles. From the general equation, an equation for the horizontal motion of a nonhomogeneous liquid is obtained, where the liquid is homogeneous in the horizontal direction and stationary.

The so-called diffusion theory of V. M. Makkaveyev considers that the motion of suspended particles is the same as the diffusional processes usually considered in a turbulent stream; i.e., he assumed that the suspended particles present are substances being transferred to the stream, but not showing a feedback effect on the dynamics of this stream.

The gravitational theory developed by M. A. Velikanov is an attempt to take into account the effects of the particles suspended in the stream on the dynamics of the carrier stream. M. A. Velikanov pointed out that it was necessary to take into account such an effect and evaluated the work of the stream. However, M. A. Velikanov did not take into account that the work indicated entered as a component in the equation for the balance of pulsation energy of the stream.

In the present paper, a stream with a small relative volume of suspended particles and small acceleration of the stream relative to the accelerating force of gravity are assumed (mention is made of the instantaneous acceleration, but not of the accelerations of the average flow). The work is based on the ideas of A. N. Kolmogorov concerning the balance of the pulsational energy of the stream. The author has wished for a long time to give his acknowledgment to this pathfinding work.

BARWIS, J. H., and HUBBARD, D. K. 1976. "The Relationship of Flood-tidal Delta Morphology to the Configurations and Hydraulics of Tidal Inlet-Bay Systems," Abstracts With Programs, Vol 812, pp 128-129.

The morphology of flood-tidal deltas is controlled by the configurations of the bays in which they occur. An aerial photographic investigation of over 100 North American tidal inlets has characterized two major types of inlet-bay systems: inlets associated with a shallow open bay (type A) and inlets associated with a channelized marsh system (type B). These configurations produce markedly different ratios of bay to ocean tidal amplitude a_b/a_o. The spatial and temporal distribution of current velocities, and thus the morphology of the resultant sand body, are distinct in each case.

In type A inlets, where a_b/a_o is small, current velocities are highest in the inlet throat and decrease rapidly away from the inlet. Sand transported into the bay by flood-tidal currents is deposited as a fanlike sheet that radiates from the inlet throat. Local hydraulics determines whether the deposit is singlelobate or multilobate with minor ebb spillover lobes, or whether it is digitate with alternating flood and ebb channels. In type B inlets, where a_b/a_o is larger, tidal current velocities decrease more uniformly away from the bayward end of the inlet channel. Sand bodies occur where current velocities are low enough to initiate sedimentation, which may be kilometres from the main entrance. Three types of channel-associated sand bodies occur: current-parallel sand stringers, sinusoidal shoals, and shielded ramp shoals. The morphology of a particular sand body is controlled by the degree of time-velocity asymmetry, and by the segregation of ebb- and flood-tidal currents. In wider type B inlets, waves effectively alter the tidally induced forms found near the inlet throat and often produce flood ramps that are welded to the adjacent marsh.

BATCHELOR, G. K. 1982 (Jun). "Sedimentation in a Dilute Polydisperse System of Interacting Spheres; Part 1, General Theory," Journal of Fluid Mechanics, Vol 119, pp 379-408.

Small rigid spherical particles settle under gravity through Newtonian fluid, and the volume fraction of the particles ϕ is small although sufficiently large for the effects of interactions between pairs of particles to be significant. Two neighboring particles interact both hydrodynamically (with low-Reynolds-number flow about each particle) and through the exertion of a mutual force of molecular or electrical origin which is mainly repulsive. They also diffuse relative to each other by Brownian motion. The dispersion contains several species of particle which differ in radius and density.

The purpose of this paper is to derive formulae for the mean velocity of the particles of each species correct to order ϕ, that is, with allowance for the effect of pair interactions. The method devised for the calculation of the mean velocity in a monodisperse system is first generalized to give the mean additional velocity of a particle of species i due to the presence of a particle of species j in terms of the pair mobility functions and the probability of distribution $p_{ij}(r)$ for the relative position of an i and a j particle. The second step is to determine $p_{ij}(r)$ from a differential equation of Fokker-Planck type representing the effects of relative motion of the two particles due to gravity, the interparticle force, and Brownian diffusion. The solution of this equation is investigated for a range of special conditions including large values of the Peclet number (negligible effect of Brownian motion); small values of the Peclet number; and extreme values of the ratio of the radii of the two spheres. There are found to be three different limits for $p_{ij}(r)$ corresponding to different ways of approaching the state of equal sphere radii, equal sphere densities, and zero Brownian relative diffusivity.

Consideration of the effect of relative diffusion on the pair-distribution function shows the existence of an effective interactive force between the two particles and consequently a contribution to the mean velocity of the particles of each species. The direct contributions to the mean velocity of particles of one species due to Brownian diffusion and to the interparticle force are nonzero whenever the pair-distribution function is nonisotropic, that is, at all except large values of the Peclet number.

BATCHELOR, G. K., and WEN, C.-S. 1982. "Sedimentation in a Dilute Polydisperse System of Interacting Spheres; Part 2, Numerical Results," Journal of Fluid Mechanics, Vol 124, pp 495-528.

Analytical formulae for the effect of interaction between pairs of rigid spherical particles on the mean velocity of each species in a statistically homogeneous dilute polydisperse system were given in Part 1 (Batchelor 1982) and are here evaluated numerically. The authors have calculated the pair-distribution function and the associated value of the sedimentation coefficient for a wide variety of conditions of the two interacting species, including different values of the ratio of the radii of the spheres λ, different values of the ratio of their (reduced) densities γ, small and large values of the Peclet number of the interaction, and different forms of the potential of the mutual force exerted directly between the two spheres. Values of λ and γ such that some of the trajectories of one sphere center moving under gravity alone relative to another are of finite length lie outside the scope of the calculations at large Peclet numbers, and the change of behavior across the boundary of this excluded set of values leads to a complicated dependence of the sedimentation coefficient on λ and γ. At small Peclet numbers the behavior is simpler, and a formula which represents the calculated values of the sedimentation coefficient over the whole range of values of λ and γ (on which the dependence is known to be linear) with fair accuracy in the absence of interparticle forces is devised. The authors' calculations of the effect of an interparticle force were based on the assumption of a high Coulomb barrier at a certain sphere separation which could be varied and a van der Waals attractive force at larger separations. It appears that the direct contribution to the sedimentation coefficient made by gravity is always appreciably larger than that made either by relative Brownian diffusion of the two interacting spheres or by the interparticle force. However, all three of these (effective) forces normally have a significant influence on the pair-distribution function and thereby also affect the sedimentation coefficient indirectly. Some published observations of the mean particle velocity in monodisperse systems are interpreted in the light of the present calculations of the effect of interparticle forces.

BEDFORD, K. W., VAN EVRA, R. E., III, and VALIZADEH-ALAVI, H. 1982 (Aug). "Ultrasonic Measurement of Sediment Resuspension," Proceedings of the Conference Applying Research to Hydraulic Practice, American Society of Civil Engineers, Jackson, Miss., 17-20 Aug 1982, pp 575-583.

Recognizing the need for improved measurement and parameterization of sediment resuspension, this paper presents a review of the major methods now in use for alleviating this need. Special attention is devoted to reviewing methods for obtaining sediment concentration profiles by acoustic scattering methods and the microcomputer-based C-DART Tower developed by the authors to measure simultaneously wave, current, and sediment profile data. The presence of spatial data requires a new approach to its analysis. A generalized pattern recognition program for geophysical flows is discussed.

BEEN, K. No date. "Non-Destructive Density Measurement Techniques for Examining Effective Stress Development in High Void Ratio Soils," Oxford University, Department of Engineering Science, Oxford, England.

The essential difference between a saturated soil and a suspension of soil particles is the existence of effective stress in the soil. By examining the sedimentation process, basic information about effective stress behavior in soft soils is obtained.

Using a method of counting X-rays passing through a soil sample, it is possible to calibrate the count rate to determine the bulk density of a soil at any level in a sample column. The method is fast, accurate, and non-destructive. From density profiles, the total stress distribution is found and combined with pore-water pressure measurements to determine the effective stress.

The technique has been used for measurements while sedimenting out a suspension of clayey silt in a 100-mm inside diameter column. A region of sediment with properties between those of a soil and a suspension is identified by steps in density and by stress distributions. Effective stresses are found in this region at high void ratios, but do not show a unique relationship to void ratio.

BEEN, K., and SILLS, G. C. 1981. "Self-Weight Consolidation of Soft Soils: An Experimental and Theoretical Study," Geotechnique, Vol 31, No. 4, pp 519-535.

The experimental observations presented in this paper are believed to be unique, because the accuracy and speed of soil density measurement achieved have not previously been reported. Considerable insight into the process whereby a soil is formed from a suspension has been gained by considering the effective stress behavior.

The concept of a unique void ratio corresponding to zero effective stress has been shown, for this particular soil at least, to be inaccurate, although it may be possible to define such a value in the normally consolidated, equilibrium state. In these experiments, the value of the void ratio at the surface of the soil layer at the end of consolidation was about 6-5.

A large strain consolidation theory, including the effect of self-weight, has been adapted to the experimental conditions. Considerable idealization has been required, but the theory is nevertheless able to predict the results of further similar experiments. A linear void ratio effective stress relationship was used, which may not be suitable over larger stress ranges. However, the changes in void ratio were large and the model was adequate in this respect. Large variations in the permeability occurred as a result of the void ratio changes, and comparison of the model with the experiments revealed the shortfalls of the idealization.

Combining the void ratio, effective stress, and permeability relationships into one coefficient of consolidation, which is assumed constant, masks the shortfalls of the separate idealizations. This would frequently not be recognized, but in this instance it was observed because the surface settlement and conditions throughout the soil column were examined.

Although the model is still rather primitive, considerable advance has been made in the ability to understand and predict settling and consolidation behavior during and after deposition from a suspension.

BELLESSORT, B. 1973. "Movement of Suspended Sediment in Estuaries-Flocculation and Rate of Removal of Muddy Sediment," Tracer Techniques in Sediment Transport, Technical Report Series No. 145, pp 31-40, International Atomic Energy Agency.

The first part of this chapter discusses the main factors governing the dynamics of estuaries, and the second part deals more specifically with the problems of flocculation and removal rate of cohesive sediments.

The study of the movement of muddy sediments in an estuary is very complex. It is necessary to determine the dynamics of the estuary, which are governed by the tide; the river discharge; the physicochemical properties of the mud (in particular the flocculation); its return to suspension, which depends on the nature of the mud and the water environment (always variable) and the flow velocity (variable in time according to tide and discharge); and, finally, the movement of the mud layer and the mud cake, the occurrence of which seems very frequent in estuaries.

BENNETT, R. H., BRYANT, W. R., DUNLAP, W. A., and KELLER, G. H. 1976. "Sediment Pore Water Pressure Experiment," Marine Geotechnology, Vol 1, No. 4, pp 327-335.

This report describes the instrumentation, initial results, and progress of an experiment designed to measure and monitor submarine sediment pore water and hydrostatic pressures in a selected area of the Mississippi Delta. The experiment also is intended to monitor significant pressure perturbations during active storm periods. Initial analysis of the data revealed excess pore water pressures in the silty clay sediment at selected depths below the mud line. Continuous monitoring of the pore water and hydrostatic pressures was expected to reveal important information regarding sediment pore water pressure variations as a function of the geological processes active in the Mississippi Delta.

BHATTACHARYA, P. K., and KENNEDY, J. F. 1971. "Sediment Suspension in Shoaling Waves," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, No. 17, 29 Aug-3 Sep 1971, pp 137-144.

A laboratory investigation of sediment suspension by shoaling waves was undertaken utilizing an electro-optical system for measurement of sediment concentration, an on-line digital computer for data analysis, and a signal-averaging technique to decompose the concentration signal into its constituent parts. Spatial and temporal distributions of the mean and fluctuating components of the sediment concentration were measured in waves breaking on equilibrium beaches in a laboratory tank. It was found that the periodic fluctuations of concentration are limited to a region extending only about 0.10 ft above the bed. The average concentration and the concentration fluctuations are distributed as a power of the distance above the bed. The sediment ripples play a dominant role in the entrainment process; a burst of sediment is entrained into suspension from each ripple crest by the water motion occurring each half wave period. At a fixed position, one to four concentration peaks may occur, depending on the location of the point relative to the ripples and the extent of the lateral excursion of the sediment clouds entrained from nearby ripple crests. The continuity equation is used together with dimensional reasoning to deduce the form of the diffusion coefficient.

BIDDLE, P., and MILES, J. H. 1972 (Jan). "The Nature of Contemporary Silts in British Estuaries," Sedimentary Geology, Vol 7, No. 1, pp 23-33.

Samples from a representative range of British estuaries were examined. Photomicrographs of suspended flocs show large sand grains supported in a diffuse clay matrix. X-ray diffraction studies show that the larger particles are almost entirely α-quartz whereas the clay fraction contains a mixture of illite, kaolinite, montmorillonite, and chlorite whose composition varies from estuary to estuary.

The sediments from one uncontaminated estuary showed very little clay but abundant detritus from living organisms. Some unidentified diffraction peaks were obtained from the sediments from this estuary.

BIEDA, G. E. 1970 (Jun). "Measurement of the Viscoelastic and Related Mass-Physical Properties of Some Continental Terrace Sediments," M.S. Thesis, US Naval Postgraduate School, Monterey, Calif.

Knowledge of the physical properties of ocean sediments has come into greater importance in recent years due to the need for a capability of predicting acoustic reflection characteristics of the ocean floor, which has become an essential part of modern sonar techniques, such as bottom bounce.

Various models of the ocean floor are being used to aid in these efforts. A viscoelastic model is favored which uses complex Lamé constants and provides for the generation of shear waves upon reflection and for absorption of the waves.

This model shows good correlation with actual results in studies done by Bucker, Anderson, and Latham in which several sets of viscoelastic constants are assumed and solutions are correlated with observed data. Although it has been demonstrated to be feasible and accurate, the viscoelastic model presents the difficulty of evaluating the Lamé constants for various ocean areas and soft sediments.

The purpose of this research described in this report was to develop and test a viscoelastometer suitable for in situ measurement and to apply it to the measurement of complex rigidity for a variety of samples of real ocean sediments. Although time did not permit inclusion of in situ measurements, the second goal was attained in these experiments. The following sections describe the theory of measurement, the improved probe's construction, calibration procedures, sample collection and analysis procedures, the limitations of the method, and results of the rigidity determinations. A discussion of the results and comparisons with other mass-physical properties are then presented.

BIGGS, R. B. 1978. "Coastal Bays," Coastal Sedimentary Environments, R. A. Davis, Jr., ed., Chapter 2, pp 69-99, Springer-Verlag, New York.

An estuary is a semienclosed coastal body of water that has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage. The landward limit of the estuary has been defined as the area where the chlorinity falls below 0.01 ppt and the ratios of the major dissolved ions change radically from the ratios in seawater. The dilution of seawater in the estuary is variable, reflecting the variability of freshwater runoff. From an oceanographic point of view, therefore, the estuary is an unstable environment. Organisms that live in the estuary are adapted to large changes in the salt concentration, and in temperate regions, to large changes in temperature. In this paper, discussion will be limited to "low-energy estuaries" characterized by low to moderate tidal current speeds. High-energy estuaries and inlets are treated in the chapter by Boothroyd (1978).

There are almost 900 individual estuaries along all the coasts of the United States, comprising an area of about 68,000 km^2. As the United States was settled, the regions around these natural harbors were the first to be developed. Cities sprang up in areas near the head of navigation. Seafood was harvested from protected estuarine waters. As the size of ships increased, dredging of previously adequate natural channels was necessary to preserve ports. As population increased, the use of the estuary for industrial and domestic waste disposal increased, affecting commercial seafood production. The population living around estuaries (approximately 60 million people live within 90 km of the coast of the United States) has placed high demands on estuaries for recreation. As a result of these competing demands for use of the estuary, such as for transportation, a waste disposal facility, a food source, and a recreational outlet, it is one of the most well-studied entities in oceanography.

BIJKER, E. W. 1982. "Physical Models for Coastal Morphology and Harbour Problems," Hydraulic Modeling in Maritime Engineering, Chapter 8, pp 87-98, Thomas-Telford Ltd, London.

The basic requirements for hydraulic morphological models are discussed. The author demonstrates that, although the phenomena are complicated, it is possible to reproduce them reliably in simple and schematized models.

BISWAS, A. N., and CHAKRABARTI, A. K. 1974 (Nov). "Sediment Transport in Tidal River," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 100, No. HY11, pp 1677-1683.

Determination of sand transport in tidal reaches is difficult due to the periodic changes in the flow direction in the upstream and downstream directions. Einstein suggested that some of the principles used in the description of unidirectional sediment motion in a river may apply in the case of oscillatory motion due to waves. The varying bed resistance associated with unsteady flow in a tidal river requires the assumption of "freezing" the tidal flow at the instant of sediment transport computation. This principle is applied to estimate the total bed material load at a section on the tidal river Hooghly in the State of West Bengal, India. The river has a well-mixed estuary.

It would appear that the principles of sediment movement in unidirectional flow are reasonably applicable to unsteady flow by freezing the tidal flow at the instant of computation. The methodology permits a quantitative assessment of sediment transport in a tidal river with well-mixed estuary with the bed material composed of noncohesive sand. Calibration of the parameters in the simplified Einstein method to suit unsteady flow conditions is necessary.

BJERRUM, L. 1954. "Geotechnical Properties of Norwegian Marine Clays," Publication No. 4, Norwegian Geotechnical Institute, Oslo.

The majority of the late glacial marine clays in Norway have been subjected to a leaching by fresh water due to a land elevation, resulting in a reduced salt concentration in the pore water.

The effect of the leaching is an essential change in the fundamental properties of the clays. Owing to a decrease in the activity of the clay minerals, the liquid limit and plasticity index are lowered. By plotting the activity--defined as ratio of plasticity index to content of clay fraction--against the salt concentration, a curve results for each clay stratum, allowing an evaluation to be made of the factors which control the activity.

The normally consolidated Norwegian clays show a linear increase in undrained shear strength with depth, which can be expressed by a constant ratio of shear strength to effective overburden pressure c/p . If for various clays this ratio is determined, a close correlation is found between c/p and the plasticity index.

As leaching out of the salt is accompanied by a reduced plasticity index, the correlation between c/p values and plasticity index indicates what happens to the undisturbed shear strength during a leaching of a marine clay. This leads to the important conclusion that the shear strength decreases with reduced salt concentration. This finding is confirmed by an analysis of a number of slides which occurred without external causes. Furthermore, a laboratory experiment shows a reduced strength after the salt has been leached out.

BOBB, W. H. 1965 (Jun). "Effects of Proposed Dikes and Sediment Traps on Shoaling and Currents in Tidewater's Delaware City Channels; Hydraulic Model Investigation," Miscellaneous Paper No. 2-723, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Based on the results of model tests reported herein and subsequent analyses of the results of these tests, conclusions have been reached with respect to the effects of the various dikes and sediment traps on shoaling and currents in the problem areas.

None of the plans tested would have any major beneficial effects on shoaling and currents in the various portions of the problem area; in fact, overall shoaling was increased for all plans tested.

The brush dikes would increase the travel time for heated water flowing from the effluent channel to reach the intake canal. This could reduce average water temperatures in the intake canal. The brush dikes would increase dispersion and mixing of the heated water. The brush dikes would trap and retain in eddy patterns some of the heated water normally carried upstream during flood tide. This could result in an increase in average water temperatures in the vicinity of the dikes, which might offset benefits as described.

The sediment traps are of insufficient size to have significant effects on dredging frequency in either the entrance channel or the intake canal. After a review of the results of these tests and the history of rapid buildup of silt immediately after dredging, it is evident that the sediment traps would be of little value in reducing dredging frequency and would probably increase the quantities of silt to be removed.

BOGGS, S., JR., and JONES, C. A. 1976 (Mar). "Seasonal Reversal of Flood-Tide Dominant Sediment Transport in a Small Oregon Estuary," Geological Society of America Bulletin, Vol 87, No. 3, pp 419-426.

The Sixes River in southwestern Oregon has a summer discharge of only about 2 m^3/sec. During these low-discharge conditions, a flood-dominated system of bottom tidal currents develops in the estuary and a deltalike sill, as much as 1.5 m in height, builds across the mouth of the estuary by upstream progradation. Flood-tide currents move across this sill at velocities of as much as 90 cm/sec 15 cm above the bottom, but the velocity of ebb-tide currents usually does not exceed about 40 cm/sec.

Dispersal patterns of dyed sediment injected at the river mouth during low river discharge show that flood-tide currents transport sand across the sill and up the estuary as far as 0.8 km (about one-fourth the length of the estuary) in a single flood-tide phase. During ebb tide, the sill impedes movement of salt water along the estuary bottom, producing a sharply stratified two-layer water system. Although tracer experiments show that some fine sand is removed from the estuary during the ebb phase, primary sedimentary structures and the mineral composition of the sand indicate that flood-tide dominance of the bottom tidal currents causes a net gain of marine sediment in the estuary while the sill is in place.

River discharge after winter storms may increase to more than 400 m^3/sec, and large quantities of detritus, including gravel, are transported downstream into and through the estuary. High river discharge also causes erosion of the sill, greatly reducing the sediment-trapping capacity of the estuary. The finer fluvial detritus, together with fine marine sediment deposited during the summer, is swept from the estuary, leaving it floored largely by gravel. Thus, the hydraulic sediment-trapping mechanisms observed in the estuary of the Sixes River appear to be effective only on a seasonal basis under present hydrologic conditions.

BOHLEN, W. F. 1975 (Dec). "An Investigation of Suspended Material Concentrations in Eastern Long Island Sound," Journal of Geophysical Research, Vol 80, No. 36, pp 5089-5100.

A 2-year record of monthly observations of suspended material concentrations at a network of 11 stations in eastern Long Island Sound is used to detail the characteristics of the concentration field and the factors governing its variability. These suspended material distributions display a high degree of spatial and temporal variability, there being only weak correlation between concentrations and concurrent salinity. This behavior contrasts sharply with observations in other regions of the sound. To determine the relative importance of hydrodynamic, meteorological, and biological factors, an ensemble average of selected station data is introduced. This average displays a seasonal variability that can be represented by the combined effects of streamflow and wind stress. Streamflow serves to produce a persistent background concentration. The occurrence of higher frequency fluctuations due to aperiodic discharge events appears limited by the volume and mixing characteristics of the eastern sound. Wind events will dominate the concentration field if high stress levels are maintained for more than 48 hr. Duration requirements are most commonly satisfied during the winter months. Materials introduced by streamflows and wind stress are distributed by the high-energy tidal stream. Biological factors exert minor influence on the variability of the concentration field.

A review of this system suggests that the eastern sound is more properly viewed as a coastal embayment than as an estuary. Mixing in this area establishes the eastern boundary conditions for the remainder of the sound.

BOILLAT, J.-L., and GRAF, W. H. 1982. "Settling Velocities of Spherical Particles in Turbulent Media," ("Vitesse De Sedimentation De Particules Spheriques En Milieu Turbulent"), Journal of Hydraulic Research, Vol 20, No. 5, pp 395-413.

To study the influence of turbulence on settling velocities, an experimental setup was developed, creating a homogeneous and isotropic turbulence. The principal elements of the installation are given. The measuring technique is then presented; hot-film anemometry is used to measure the turbulence and video equipment is used to study the settling characteristics. The results of the turbulence study are given and compared with other experimental and theoretical data.

The results of the settling study for different spherical particles settling in different turbulent media are given in form of a drag coefficient (Cd) vs particle Reynolds number (RE) relationship. It is to be noted that Cd is in some cases superior and in others inferior when compared with the nonturbulent data. For all RE studied, it was found that Cd's diminish if the turbulent velocity u' increases and simultaneously the macroscale L decreases. Around an RE of 2,000, Cd's show a distinguishable "hump," whereby they may fall above the nonturbulent data. The study's conclusion is that the present experimental data are best represented with the dimensional parameter u'/L .

BOKUNIEWICZ, H. J., GEBERT, J., and GORDON, R. B. 1976 (Sep). "Sediment Mass Balance of a Large Estuary, Long Island Sound," Estuarine and Coastal Marine Science, Vol 4, No. 5, pp 523-536.

Acoustic reflection profiles and bottom sampling are used to measure the volume of sediments accumulated in Long Island Sound. There is presently 1.0×10^{10} m^3 of sediment of which 5.3×10^9 m^3 is marine mud and 4.9×10^8 m^3 is probably of pre-marine, lacustrine origin. The balance consists of re-worked sand derived from glacial drift. The acoustically determined subbottom structure of the sound and available sea level data indicate that the sound basin was occupied by a large lake for at least 6,000 years and has been an arm of the sea since 8,000 years BP. The volume of lacustrine sediment is accounted for by direct riverine input over 6,000 years, but the volume of marine mud present substantially exceeds the riverine supply over 8,000 years. The sound is shown to act as a trap for sediments originating on the continental shelf.

BONACCI, O. 1981. "Accuracy of Suspended Sediment Measurements in Natural Streamflows," Journal of Hydraulic Research, Vol 19, No. 3, pp 195-209.

The paper deals with the problem of assessing the accuracy of suspended sediment measurements in open streamflows. The essentials of the gravitation and diffusion theory are presented in the introduction together with practical examples of measurements on the Drava River. Employing a Monte Carlo method and the theory of experimental design, the discharge of suspended sediment through a schematic cross section of an open streamflow was simulated. The influence of the following five factors on the accuracy of suspended sediment measurements is examined:

a. The number of verticals on which the suspended sediment measurements are carried out.

b. The number of points at which measurements are conducted.

c. The position of the points on the verticals.

d. The position of the verticals in the cross-sectional area.

e. The vertical distribution of suspended sediment concentration.

The analysis showed that, in suspended sediment measurements in natural streamflows, great attention should be paid to the selection of the number and position of the verticals. Recommendations for optimizing measurements are given. The formula for determining the upper limit of absolute error in suspended sediment measurements is also defined. The influence of different measurement methods on the annual budget of suspended sediment is investigated.

BOOTHROYD, J. C. 1978. "Mesotidal Inlets and Estuaries," Coastal Sedimentary Environments, R. A. Davis, Jr., ed., Chapter 6, pp 287-360, Springer-Verlag, New York.

It is evident from the models discussed in preceding chapters that even though there are copious maps of sedimentary structures, depicting an instant in geologic time, there is limited information on stratigraphic sequences deposited over time, based on recent depositional models. "Hypothetical" and "inferred" are the terms often used, even for sedimentary structure distribution. The studies by Greer and Kumar and Sanders are quite useful because they are based on information from box cores. Another problem is the matter of preservation potential; Hubbard and Barwis specifically address this problem in the variation between their two models. Perhaps the best way to approach the regressive versus transgressive and preservation potential problems is to consider geologic processes and resulting distribution of inlet features as they exist today and have existed during the late Holocene transgression.

Presently, sea level is rising at the relative rate of 30 cm per 100 years for most of the United States east coast. In addition, most barrier islands and spits show long-term (40-150 years) trends of 1-10 m/year of beach erosion caused by storm wave attack and lack of sediment supply. Last, there is some documented evidence to support the general observation that flood-tidal deltas show a long-term accretional trend.

Computations by Finley indicate the ebb-tidal delta of North Inlet, South Carolina, is enlarging at the expense of the eroding nearby barrier spits. Unpublished data of Hine indicate the preservation of inlet sequences (ebb-tidal deltas) within the shoreface and inner continental shelf stratigraphy of southern North Carolina. Observation of the beaches of many east coast United States barrier islands shows salt-marsh peat cropping out on the beach face near mean low water, particularly after storm events.

Conclusions drawn are as follows: (a) ebb-tidal deltas may be preserved as regressive sequences within shoreface successions; (b) the process of barrier island retreat perhaps removes the topmost units of the flood-tidal sequence and most likely all of the upper barrier spit sequence; and (c) flood-tidal delta and bay-lagoon sediments are preserved as regressive sequences.

BOSWORTH, R. C. L. 1956 (Feb). "The Kinetics of Collective Sedimentation," Journal of Colloid Science, Vol 11, pp 496-500.

The empirical law connecting the relative volume x of the precipitate with its relative life period y may readily be differentiated to give an expression for the rate of settling at any particular stage.

For a liquid settling in a tube of constant sectional area, an alternative expression for x reads:

$$x = \frac{h}{h_\infty} \tag{1}$$

where h is the height of the top of the precipitate at any time t and h_∞ is the final height. The variable y correspondingly becomes

$$y = \lambda t \tag{2}$$

where λ is a measure of the rate of settling in some standard state and as such is related to the mean particle size and average particle shape. Equation 1 now becomes

$$\frac{h}{h_\infty} - 1 = \frac{0.95}{\lambda t} \tag{3}$$

The concentration C of the suspension is related to the ratio of h_∞ to h ; and if the final volume, because of water immobilized between particles, is some multiple k of the true volume of the suspended particles, then

$$C = \frac{h_\infty}{kh} \tag{4}$$

BOWDEN, K. F., and HOWE, M. R. 1963. "Observations of Turbulence in a Tidal Current," Journal of Fluid Mechanics, Vol 17, pp 271-284.

This is a study of the longitudinal and vertical turbulent velocities which were measured both near the surface and near the bottom of an estuarine tidal current. The turbulence spectra, representing mainly the energy-containing eddies of the flow, were derived, and it was also possible to determine values for the Reynolds stresses at different depths and to make an estimate of the scales of the turbulence. The results are compared with similar observations in the open sea, and certain features are discussed which resemble those of measurements of turbulent flow in laboratory experiments and in the atmosphere.

BOWEN, A. J., NORMARK, W. R. and PIPER, D. J. 1984. "Modeling of Turbidity Currents on Navy Submarine Fan, California Continental Borderland," Sedimentology, Vol 31, pp 169-185.

Several Holocene turbidities can be correlated across much of Navy Fan through more than 100 sediment core localities. The uppermost muddy turbidite unit is mapped throughout the northern half of the fan; its volume, grain-size distribution, and the maximum height of deposition on the basin slopes are known. These parameters can be related to the precise channel morphology and mesotopography revealed by deep-tow surveys. Thus there is sufficient information to estimate detailed flow characteristics for this turbidity current as it moved from fan valley to distal basin plain.

On the upper fan, the gradient, the increasing downstream width of the channel, and only limited flow overspill suggest that the flow had a Froude number close to 1.0. The sediment associated with the channel indicates friction velocities of about 0.06 m sec^{-1} and flow velocities of about 0.75 m sec^{-1}. Using this flow velocity and channel dimensions, sediment concentration ($\approx 2 \times 10^{-3}$) and discharge are estimated; and from a knowledge of the total volume of sediment deposited, the flow duration is estimated to be from 2 to 9 days. It is shown that the estimates of Froude number, drag coefficient, and sediment concentration are not likely to vary by more than a factor of 2.

On the midfan, the flow was much thicker than the height of the surface relief of the fan, and it spread rapidly. The cross-flow slope, determined from the horizontal extent of turbidite sediment, is used to estimate flow velocity, which is confirmed by consideration of both sediment grain size and rate of deposition. This again allows sediment concentration and discharge to be estimated. The requirements of flow continuity, entrainment of water during flow expansion, and observed sediment deposition provide checks on all these estimates, and provide an integrated picture of the evolution of the flow. The flow characteristics of this muddy turbidity current are well constrained compared to those for more sand-rich late Pleistocene and early Holocene turbidity currents on the fan.

BRIDGE, J. S., and DOMINIC, D. F. 1984 (Apr). "Bed Load Grain Velocities and Sediment Transport Rates," Water Resources Research, Vol 20, No. 4, pp 476-490.

After a brief discussion of the mechanics of bed-load motion, this paper develops a theoretical model for bed-load sediment transport rate with a comprehensive discussion of the hydraulic parameters used. All aspects of the theory are then evaluated.

Through a theoretical consideration of the dynamics of bed-load motion, following the work of R. A. Bagnold, expressions for grain velocity U_b and sediment transport rate i_b are obtained as

$$U_b = a(U_* - U_{*c})$$

$$i_b = \frac{a}{\tan \alpha} (\tau_o - \tau_c)(U_* - U_{*c})$$

where U_* is the shear velocity of the fluid, τ_o is the shear stress of the fluid, and U_{*c} and τ_c are critical values which initiate grain motion.

The grain velocity equation accurately predicts the velocity of single grains over a fixed rough bed when a is allowed to vary with bed roughness and saltation height of the grains. As such grains override the fixed boundary, values of U_{*c} are considerably less than those for loose beds of coplanar grains.

The bed-load transport rate equation accurately describes plane bed data as sediment transport rate increases by a factor of 10^5. Values of $a/\tan \alpha$ increase significantly from lower stage plane beds (9.5) to upper stage plane beds (17). This is due to an increase in a with suspended sediment concentration but also to a decrease in $\tan \alpha$, as predicted by Bagnold. Tan α also decreases as grain size increases, as Bagnold predicted, but Bagnold's values must be increased by a factor of at least 1.6 in the stream case. The parameter $(U_* - U_{*c})/V_g$ where V_g is the grain settling rate can be used to predict $a/\tan \alpha$ values. The threshold of grain motion is well described by modern Shields-type curves.

BROGDON, N. J., JR. 1976 (Apr). "Grays Harbor Estuary, Washington: 45-Ft MSL (40-FT MLLW) Navigation Channel Improvement Studies; Hydraulic Model Investigation," Technical Report H-72-2, Report 6, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The existing, comprehensive fixed-bed model of the Grays Harbor estuary was used to determine the effects of enlarging (deepening and widening) the existing 35-ft-deep channel to a depth of 45 ft referred to mean sea level. One 45-ft improvement plan consisting of 23 groins and a relocated turning/settling basin was also investigated. Model tests were conducted on these plans to determine effects on tidal heights, current velocities and patterns, salinity intrusion, dye dispersion, and channel shoaling. The scope of data collected while testing the improvement plan was not as extensive as for the enlarged channel itself; however, the data obtained were considered sufficient to define the effects resulting from the plan.

The enlarged channel caused the following changes: (a) Maximum current velocities were reduced by less than 0.5 fps. (b) Very little change occurred in tidal heights or phase of tide. (c) Bottom ebb flow predominance was decreased along the navigation channel upstream from Crossover Channel. (d) Surface ebb flow predominance was increased along the entire length of the navigation channel. (e) Salinity values in the upper reaches of the estuary were increased, thus increasing upstream intrusion of the salinity wedge. (f) Peak dye concentrations resulting from dye released near Cosmopolis were generally increased at the surface elevations and decreased at the bottom elevations. Peak concentrations generally arrived at most stations about one tidal cycle later than those observed during base test conditions. It appeared that water quality at many areas in the estuary resulting from a pollution source at Cosmopolis would be degraded. (g) Dye concentrations resulting from a dye release at the bottom in the estuary entrance were increased throughout the estuary. This dye source, however, actually represents a source of relatively clear seawater. (h) Channel shoaling rates would be increased less than 15 percent at Moon Island reach and Cow Point, Aberdeen, and South Aberdeen reaches; unchanged in the Crossover Channel reach; and decreased less than 10 percent in the Hoquiam and Sand Island Shoal Channel reaches. The shoaling would be more evenly distributed over most channel reaches, thus requiring less frequent dredging operations to maintain channel depths over the peak shoal areas.

BRONFMAN, A. M., and ALEKSANDROV, A. N. 1966. "The Don Estuary as an Example of Sedimentation in Marine Shallows in Front of an Estuary," Oceanology, Vol 5, No. 4, pp 68-75.

The distinguishing features of sedimentation in the coastal shallows off the Don estuary are largely determined by the dynamics of its waters and proceed differently in different hydrometeorologic situations, and in different development stages of these situations.

BROWN, C. B. 1949. "Sediment Transportation," Engineering Hydraulics, H. Rouse, ed., pp 69-99, John Wiley and Sons, Inc., New York

This chapter deals with the nature and mechanics of entrainment, movement, and deposition of fragmental solid particles by flowing water and the application of this information to practice field problems met with in canals, rivers, reservoirs, and coasts.

BRUUN, P. 1980 (Jul). "Siltation in Estuaries," Terra et Aqua, No. 19, pp 7-15.

This paper reviews siltation problems in estuaries and their causes. It mentions how conditions in siltation may be improved by training walls and by dredging. Due to environmental problems, new dredging methods are now being tested, including controlled agitation.

BULLER, A. T., and McMANUS, J. 1979. "Sediment Sampling and Analysis," Estuarine Hydrography and Sedimentation, K. R. Dyer, ed., pp 87-130, Cambridge University Press, Cambridge, England.

The aim of this paper is to provide an outline of the principal methods of obtaining samples of sediment, the manner in which these materials may be processed in the laboratory to determine particle sizes, and some general statement on how sediment size analyses may be used to provide information about an estuary. The chapter is not intended to serve as a comprehensive manual for all sampling equipment and methods of grain-size determinations but rather to provide a guide to the main apparatus and analytical methods commonly employed in studies of estuarine sediments. Many laboratory manuals exist which deal with procedures, some excellently detailed, and the reader is referred to these if greater detail is required for any method outlined. Useful reference texts are Krumbein & Pettijohn (1938), Irani & Collis (1963), Muller (1967), Allen (1968), Carver (1971), and Folk (1974), which may be profitably supplemented from British Standard 1377 (1975) and publications of the American Society for Testing Materials. Sampling apparatus is reviewed in Hough (1939), Shepard (1973), and Kelland (1975).

BURNS, R. E. 1963. "Importance of Marine Influences in Estuarine Sedimentation," Symposium 3; Sedimentation in Estuaries, Harbors, and Coastal Areas, Miscellaneous Publication 970, Paper 64, Federal Inter-Agency Sedimentation Conference, Jackson, Miss., 28 Jan-1 Feb 1963, pp 593-598.

Most estuarial studies are conducted in river-dominated estuaries (major rivers), where marine sediment sources are overshadowed by river loads. Five possible sediment behaviors are (a) through and out, (b) through and out in steps, (c) permanently deposit, (d) deposition and erosion, (e) deposition-erosion, continuing. All could be operating simultaneously on different particles. The most frequently overlooked source of sediment is the seaward end of the estuary. Marine influences induce density currents, wave action, tidal asymmetry, and estuarine circulation in general.

C

CACCHIONE, D. A., ROWE, G. T., and MALAHOFF, A. 1978. "Submersible Investigation of Outer Hudson Submarine Canyon," Sedimentation in Submarine Canyons, Fans, and Trenches, D. J. Stanley and G. Kelling, eds., Chapter 4, pp 42-50, Dowden, Hutchinson and Ross Inc., Stroudsburg, Penn.

Data collected in the submersible *Alvin* during four dives into outer Hudson Canyon reveal that active erosion of the canyon walls and floor is occurring at water depths between 2,900 m and 3,600 m. Visual observations and sedimentary analyses of shallow cores obtained by *Alvin* indicate that strong bottom currents and benthic organisms have reworked the surface sediments of the canyon floor. Moats around the bases of erratic boulders and undercut bases of the rock walls provide additional evidence that bottom currents, flowing in a downcanyon direction, erode the canyon sediments and cut back the walls. This active erosion by strong bottom currents is probably an episodic process, because current measurements obtained on *Alvin* and with two moored current meters during the 4-day dive period were consistently weak (speeds less than 15 cm/sec). Extensive burrowing, prevalent at each dive site, has probably contributed significantly to the erosion of the canyon walls.

CAMP, T. R. 1946. "Sedimentation and the Design of Settling Tanks," Transactions, American Society of Civil Engineers, Vol III, Paper No. 2285, pp 895-958.

Sedimentation has been used for generations to clarify liquors and to concentrate solids in many widely diversified fields. It is the most commonly used process in the field of water and sewage treatment. The investments for settling tanks in this field are probably about one-third of the total capital investment for treatment. Despite the importance of the process, current understanding of the principles involved has progressed so slightly that there is as yet no such thing in practice as the economic design of tanks from a functional viewpoint. The dimensions of most settling tanks are fixed on the basis of standard detention periods recommended by state health departments. This practice prevails in disregard of the fact that evidence was presented as early as 1904 that removal of suspended matter depends upon surface area and not upon tank volume. The settling characteristics of the suspensions to be clarified are rarely considered in the design of settling tanks.

The purpose of this paper is to collect in one compendium the known principles of sedimentation essential to the development of design theory, and to present the theory of design developed to a stage which will permit its use in practice. The paper is divided into ten interrelated topics. Much of the subject matter is the work of others, and due credit is given by means of references. The use of the theory is illustrated by a number of practical examples. It has been necessary to omit a discussion of the design of inlets and outlets because of lack of space.

CARDER, K. L., and MEYERS, D. J. 1980 (Sep/Oct). "Holography of Settling Particles: Shape Parameters," Optical Engineering, Vol 19, No. 5, pp 734-738.

The effect of shape on the fall velocity of silt-size mineral particles was investigated by recording sequential transmission holograms of settling particles. Particles with similar densities and settling speeds varied in their sphere-equivalent radii by a factor of 5. The large particles were edgewise-settling thin flakes while the smaller particles were much more compact. Variations of the Stokes' settling equation for thin disks accurately described the settling data for large thin flakes. The fall velocities for small, compact, fast-settling particles were much greater than for volume-equivalent spheres and were adequately described by the Stokes' equation for elliptical cylinders. An unresolved problem remains in that the theoretical drag on thin disks is about four times that on flat elliptical cylinders of the same surface area.

CARDER, K. L., STEWARD, R. G., and BETZER, P. R. 1982 (Jul). "In Situ Holographic Measurements of the Sizes and Settling Rates of Oceanic Particulates," Journal of Geophysical Research, Vol 87, No. C8, pp 5681-5685.

A free-floating sediment trap equipped with a holographic particle velocimeter (HPV) was deployed for 14.4 hr at a depth of 30 m in the western North Atlantic Ocean. The system recorded the in situ sizes, shapes, orientations, and settling rates of microscopic particles moving through the laser beam. The primary data reduction revealed particles from the system's lower limit of resolution, 15 μm in diameter, to 250 μm in diameter with settling velocities ranging from 0.0190 to 0.2302 cm/sec (16-198 m/day). Individual particle densities, calculated from a modified Stokes' equation, ranged from 1.37 to 5.10 g/mℓ. The presence of high-density particles was independently corroborated through individual particle analysis of the trapped material with a computer-controlled, scanning electron microscope equipped with an energy dispersive X-ray analyzer. In the future, in situ holographic systems might be used to further understanding of primary productivity, sediment erosion/ deposition, and particle aggregation/disruption/dissolution.

CARGILL, K. W. 1983 (Jan). "Procedures for Prediction of Consolidation in Soft Fine-Grained Dredged Material," Technical Report D-83-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The report documents studies refining the procedures for calculation of one-dimensional consolidation behavior of very soft fine-grained dredged material. Both the conventional small strain theory of consolidation, which requires linear or constant soil properties, and the more general finite strain theory, which provides for nonlinear soil properties, are presented. Implications of the simplifying assumptions necessary in practical application of the theories are discussed, and the general finite strain theory is shown to be superior for the treatment of dredged material.

The governing equations for both theories are written in nondimensional terms, and appropriate boundary and initial conditions are specified. Solutions in terms of figures relating the percent consolidation to the nondimensional time factor for small strain theory have been previously published. However, similar solutions based on the finite strain theory were not available and thus had to be developed. Using a computer program, a linearized nondimensional form of the general finite strain governing equation was solved for the cases of singly/doubly drained normally consolidated clays, and singly/doubly drained dredged fill. The figures given represent a significant advancement in the ability to accurately predict the consolidation behavior of thick deposits of very soft fine-grained materials having nonlinear soil properties. A method of obtaining soil parameters necessary for use of the new solution charts is proposed.

A procedure for calculating consolidation of multiple lifts of material placed on prior lifts of underconsolidated material is also proposed and validated by using the procedure to predict settlements of actual field sites where settlements have been measured. For two of three field sites, good agreement was obtained between predictions and measurements when the finite strain theory and the proposed solution technique were used. Behavior at the third site was not well predicted due to the geometry of the site and its particular filling history. In all cases, the finite strain theory solutions were far more accurate than small strain theory solutions. The calculation procedure is also applicable to a single lift subjected to multiple surcharge loadings as would be the case in a phased construction.

CARLING, P. A. 1982 (Feb). "Temporal and Spatial Variation in Intertidal Sedimentation Rates," Sedimentology, Vol 29, No. 1, pp 17-23.

Sediment deposition and erosion rates are reported for an intertidal zone in the Burry Inlet, South Wales.

Measured deposition rates over the salt marsh are compared with deposition rates calculated from observed suspended sediment concentrations. Notably, it is concluded that residual turbulence at slack water should not be discounted when calculating deposition rates.

Grain-size distributions of suspended sediments over the marsh surface during flood and ebb tides contrast with the grain-size distribution of deposited marsh sediments, the latter being significantly coarser. These data in conjunction with mass budget calculations are used to relate total annual deposition and sediment supply by tidal action during settled meteorological periods. The analysis suggests that episodic storm-induced sediment transport is probably an important mechanism for introducing coarse sediment onto the marsh surface.

Finally, it is noted that seasonal reworking of the sandy noncohesive sediments may be related to variations in the intensity of wavebreaking throughout the year.

CARLSON, E. J., and ENGER, P. F. 1962 (Oct). "Studies of Tractive Forces of Cohesive Soils in Earth Canals," Report No. HYD 504, US Department of Interior, Bureau of Reclamation, Hydraulics Branch, Denver, Colo.

A field and laboratory study was made to develop a method for determining critical tractive forces of cohesive earth materials for the design of unlined and earth-lined canals. It is desirable to know the critical tractive force value of proposed earth canal materials and to use critical tractive force as a criterion in designing earth canals. Critical tractive force is a more precise value than estimated permissible canal velocities on which to base the design. When the critical tractive force value is known, the methods of design outlined can be used to give the most efficient design for the canal.

Soil samples were obtained from 46 test reaches in various sizes of canals and laterals constructed on Bureau projects. Soil and hydraulic tractive force properties were measured and computed in the laboratory. The properties measured or computed were critical tractive force from the hydraulic erosion machine, liquid limit, plasticity index, soil density, percent of maximum Proctor density, shrinkage limit, soil gradation using the logarithmic probability method of analysis, and unit vane shear values.

CASTAING, P., and ALLEN, G. P. 1981. "Mechanisms Controlling Seaward Escape of Suspended Sediment from the Gironde: A Macrotidal Estuary in France," Marine Geology, Vol 40, pp 101-118.

The main parameters controlling suspended sediment transport in and out of the Gironde estuary are riverflow and tides. These combine to control water mixing, density circulation, and the trapping of suspended sediment in the turbidity maximum. Seaward escape of sediment is related to the position of the maximum in the estuary, which is a function of riverflow, and the amount of sediment in suspension as controlled by tide range. Seaward escape of sediment appears to follow two cycles: (a) a 14-day neap-spring tidal cycle, and (b) a seasonal riverflow cycle. Maximum escape occurs during spring tides and high river flow. During these periods, the turbidity maximum is located downstream in the estuary and the increased seaward surface density flow supplies to the shelf large quantities of suspended sediment. At this time, net seaward flux is more than 100 times that measured during conditions of low river flow.

Thermal imagery and aerial photography in the inlet, repeated during a spring tide cycle, show an initial seaward drift of the surface estuarine water and suspensions, followed by a northward transport and mixing with water from the adjacent inlet. In succeeding tides, the turbid plume is dispersed, fragmented, and transported seaward and to the north in the coastal drift system. Most of the suspended sediment expelled from the estuary is deposited on the shelf between 30- and 70-m depth, where wave resuspension is low and where suspended sediment concentrations are high enough to supply and maintain a permanent mud deposit.

CEDERWALL, K., and SVENSSON, T. 1976 (Jul). "Sediment Flushing after Dredging in Tidal Bays," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 102, No. HY7, pp 935-953.

Generally, dredging operations have the undesired effect of bringing bottom material into suspension. When the sediment particles carry pollutants or when the area adjacent to the dredging site is sensitive to environmental disturbances, the spreading of this suspended material must be controlled.

A one-dimensional segmentized model is proposed for predicting the rate of transport of suspended material in the case of a shallow tidal bay or estuary. In particular, the model is designed to estimate the escape of such suspended sediment from the bay. The model considers separately the effects of the longitudinal transport (diffusion and freshwater through flow) and the resedimentation of the sediment particles or flocs. These two transport modes are superimposed in the form of a dispersion function $D_{ij}(t)$, supplemented by a sedimentation factor $G(H/t)$. This approach for dealing with the sediment transport problem is subject to certain restrictions considered in the paper. The applicability of the proposed model depends primarily on the possible effect of turbulence upon the sedimentation mechanism and the rate of resuspension. In the model, these effects were neglected.

The suggested model for tidal flushing of sediment was calibrated in the actual dredging area. A fluorescent tracer was continuously released in the freshwater outflow of the bay, and the distribution along the bay of tracer concentration and salinity was recorded. To ensure adequate reproduction of the resedimentation effect, sedimentation analysis was carried out on sediment samples taken from the bay to be restored. These samples were divided into one organic part (polluted top sludge layer) and one inorganic part, which were analyzed separately. The calculations showed that for this particular water area a minor fraction of the suspended material produced by the dredging would escape into the adjacent waters.

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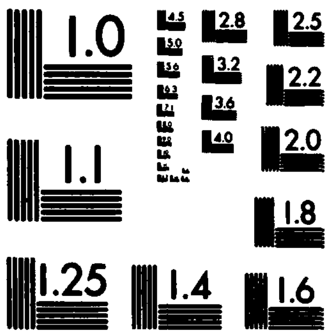

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

CHANG, H. H. 1980 (May). "Stable Alluvial Canal Design," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 106, No. HY5, pp 873-891.

For a channel in regime, the water discharge, sediment discharge, channel geometry, and slope, among other flow variables, should be in equilibrium. In other words, for any given water discharge and sediment discharge in an alluvial channel, the flow will eventually establish its boundary by adjusting the width, depth, and slope of the channel over a period of time. For the design of canals, regime formulas have been developed by many investigators, notably by Lacey, Inglis, Blench, Simons, etc. Most regime formulas consist of three independent equations that are solved for the three degrees of freedom in channel width, depth, and slope. The regime researchers obtained data from regime channels and developed relations among the hydraulic and sediment parameters for these channels.

Among the independent relations for regime channels, the flow resistance formula and sediment transport formula have been studied by many investigators. If the formulas for flow resistance and sediment transport are selected as two of the required three equations, only one additional equation will be needed to describe completely the flow in a regime channel. In searching for the third equation, the equilibrium state of an alluvial channel is considered. The equilibrium condition for the regime channel, as well as graded streams treated by geologists, may be conceptually considered as the condition of minimum stream power for an alluvial channel. Mathematically this condition can be regarded as the third equation. The three equations can thus be solved for the three unknowns. Some canal data are used herein for substantiation of this approach.

In a previous study, Chang and Hill applied these three equations to compute the variation of the stream geometry on a delta. The delta stream, which is unconstrained in this width and depth, may be concentrated or braided in flow pattern depending on the degradation or aggradation of the stream. In application, these three equations can generally be used to compute the width, depth, and slope of a stable alluvial channel. This paper reports the general treatment of the regime canal by using three such conditions. Using a trapezoidal approximation for the cross-sectional shape and a given side slope related to the bank material, the geometry of a channel is uniquely defined by its width and depth.

CHANG, S.-C. 1972 (Jun). "Computer Simulation of Flocculent Settling," Ph.D. Dissertation, Northwestern University, Evanston, Ill.

This study develops a simulation model of flocculent quiescent settling in order to better understand the flocculent settling process as well as to bring to light many quantitative and qualitative aspects of the process which otherwise may be difficult to obtain. The simulation model is so structured that the settling and flocculation of particles and their interactions are considered. The hindered settling of particles and the breakup of particles are also included in the model.

The model is successfully applied to study the removal of flocculent suspensions in an ideal plug flow sedimentation tank, and the effect of flocculation on the removal is also examined. The results clearly demonstrate that the removal of flocculent suspensions in an ideal tank is a function of both overflow rate and depth of the tank. The removal efficiency is generally significantly improved by flocculation, indicating a less significant role of hindered settling. With a very large or small overflow rate, however, the difference in the removal between flocculent settling and discrete settling becomes insignificant. The removal of flocculent suspensions by settling is shown to increase with a higher mass density of the particles, a greater collision efficiency factor, and to a lesser extent, by a larger concentration of particles.

Flocculent settling in a quiescent column is also studied with the simulation model, and the effect of flocculation on the evaluation of particle size by sedimentation analysis is also investigated. The irregular concentration profile generally observed during settling suggests that any interpretation derived from the concentration profile obtained from inadequate observation could be seriously misleading.

The results of this study indicate that the simulation model offers considerable potential for further studies of many interacting phenomena which influence the flocculent settling process.

CHANUT, J.-P., and POULET, S. A. 1982 (Nov). "Short-term Variability of the Size Spectra of Suspended Particles in a Rapidly Changing Environment," Estuarine, Coastal and Shelf Science, Vol 15, No. 5, pp 497-513.

Analysis of suspended matter collected in the lower St. Lawrence estuary indicated short-term variabilities in both the structure and dynamics of the particles. Variations with time and depth were ascribed to fluctuation of particle concentrations within the size ranges of the major peaks of concentration. A deterministic pattern was found for the temporal succession of the spectra when total particle concentrations were high. This was due to combinations of three factors that act in one of two ways, either (a) high current velocity-spring tide-stratified waters, or (b) lower current velocity-neap tide-mixed waters. In the first case, the current effect prevailed, while the tide effect was dominant in the second one. A random pattern occurred in the succession of the spectra when lower particle concentrations and patches of smaller dimensions were present in well-mixed water bodies. Successions of spectra were not always in phase at different depths within the water column.

CHASE, R. R. P. 1979. "Settling Behavior of Natural Aquatic Particulates," Limnology and Oceanography, Vol 24, No. 3, pp 417-426.

The validity of Stokes' law as an approximation to the drag force on sediments (organic-mineral aggregates) from lacustrine and marine environments was examined under controlled laboratory conditions. The settling characteristics of aggregates in the size range of 5-500 μm were consistent with a Stokesian assumption. Experiments with distilled, organics-free, and natural waters indicated that aggregate behavior is altered by the presence of naturally occurring surface coatings, solution electrolytes, and dissolved organic substances.

Although rotational effects appear unimportant, the above factors combine to produce a reduction in overall nonlinear skin friction which is manifested by up to an order of magnitude increase in velocity over the predicted value for an aggregate of mean dimension (~28.5 μm).

CHAUNG, S. C., and GOLDSCHMIDT, V. W. 1974 (Mar). "Turbulent Diffusion in Liquid Jets: Final Report," EPA 660/3-74-004b, US Environmental Protection Agency, Washington, DC.

Laboratory studies were conducted on the dispersion of gas droplets of different sizes in turbulent water jets. The main purpose was to determine the turbulent transport coefficient of contaminants suspended in turbulent flows.

The experimental results were compared to measurements of diffusion of liquid droplets in air jets as well as to a numerical analysis based on the equations of motion of the particles themselves.

The results confirm that small particles in turbulent flows have an increasing turbulent transport coefficient with size. The collated experimental results exhibit when Reynolds analogy (in the transport of mass and momentum) can be validly employed.

CHIOU, W. A., SHEPHARD, L. E., BRYANT, W. R., and LOONEY, M. P., III. 1983. "A Technique for Preparing High Water Content Clayey Sediments for Thin and Ultrathin Section Study," Sedimentology, Vol 30, pp 295-299.

The study of sediment microfabric is fundamental to the understanding of various sediment properties including shear strength, compressibility, and permeability; evaluating depositional environments; and investigating clay diagenesis. A technique is presented which preserves the particle integrity of fine-grained sediments while permitting examination of the same sample using light and electron microscopy techniques. The technique involves drying the sediment sample using a critical point drying apparatus and then impregnating it using low-viscosity SPURR epoxy. Standard thin sectioning techniques are used for light microscopy, whereas ultrathin sections are made using a microtome for transmission electron microscopy work. Scanning electron microscopy investigations are performed on samples prior to impregnating.

CHMELIK, F. B. 1970 (Jan). "An Investigation of Changes Induced in Macrostructures of Pelitic Sediments During Primary Consolidation," Texas A&M University, Department of Oceanography, College Station, TX.

This investigation of consolidation-induced changes in macrostructures is based on (a) the use of stereo X-ray radiography to map the macrostructures prior to and following consolidation and (b) a comparison of changes induced in artificial and natural macrostructures. Homogeneous marine clay, fine-grained quartz sand, and CuO powder were used to make twenty-two geometric macrostructures. An electroosmotic cutting device was developed to facilitate model fabrication.

Several types of coring devices, including two flexible liner corers developed for this study, were used to collect cores from a variety of depositional environments.

Electrical logging techniques and X-ray radiography were used to locate and identify macrostructures in the cores. The cores were cut longitudinally to allow photography, half-core X-ray radiography, and visual inspection of the structures. Selected macrostructures were removed from the core halves, rejoined, and loaded into polyvinyl chloride consolidometer cylinder liners.

Stereo X-ray radiographs were made in at least two orientations, both immediately prior to and following consolidation of all models. Primary consolidation for a load of 32 tons per square foot was effected on the macrostructures in Anteus back pressure consolidometers.

Comparisons of the macrostructure changes induced during consolidation of the artificial structures with those of the natural structures indicate the existence of a positive relationship. Several conditions are imposed before the natural and artificial structures can be related. These conditions include that both structures be of similar materials and subjected to similar conditions of consolidation. This relationship may allow the analysis of consolidated natural macrostructures by comparison with consolidated artificial models and possibly lead to a method of relating the natural macrostructures to their environment of deposition.

CHOU, T. L. 1971. "Study of Transportation of Sediment Materials in Rivers and Estuaries by Means of Models," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, No. 8, 29 Aug-3 Sep 1971, pp 59-72.

Due to the intensive studies in recent years of sediments in rivers and estuaries, it is realized that the research has arrived at a new stage which calls for a shift of points of interest. Instead of numerical data alone, more attention should be paid to the mechanism of the phenomenon. In other words, investigation should move a bit from empiricism to rationalism.

In this experiment, two kinds of solid particles in each typical category of gravel, sand, and silt are tested in a 16-ft-long, 6-in.-wide flume for the motions of particles and the bed forms. It is found out that ripples are excited by and synchronized with water waves. Dunes are formed from erosion and transportation of particles by the kinetic energy of flow. It is also learned that the various stages of solid movement are closely related to the stages of fluid motion which indicates the mutual actions of flow and wave propagation. It is surmised that fine particles in suspension may also move in the successive stages of undulation and smooth translation. Fine particles like loess have very peculiar motion of bed load transportation in the form of suspension. Finally it is proposed, together with the investigation of inherent mechanics, that some parameters are required to define the different stages of motion. In conclusion, fluid with or without solids moves in stages of undulations interposed with smooth stages.

CHRISTENSEN, B. A., and ALTSCHAEFF, A. G. 1965 (Sep). "Erosion and Deposition of Cohesive Soils," *Journal, Hydraulics Division, American Society of Civil Engineers,* Vol 91, No. HY5, pp 301-308.

The author's investigation of erosion of cohesive soils by water concluded that erosion occurs by removal of individual clay particles or clusters of particles, provided flow induces shear stresses less than the shear strength of the soil. It was further concluded that such resistance to erosion appeared to be independent of the macroscopic shear strength of the bed.

Experiments have shown that "the erodibility of a certain clay to a given mechanical influence is greatest in the case of high content of a dispersing agent in the water. The liability of a clay to become dispersed depends on its type, content of humic gels, salinity, etc. In the presence of water, clay will be disaggregated to an extent which is also dependent on the properties of the water, i.e., its content of dispersing agents." It would appear that the properties of the water play a strong role in the resistance a clay offers to erosion. As the author's tests were conducted with water only at ocean salinity, the influence of the water quality on erosion rate could not be determined.

The foregoing suggests that susceptibility to erosion is not as strongly influenced by the state of compaction (or densification) as was previously believed. In fact, it may be that erosion of clay, whether in the bed of a stream or at the sides of a crack that has developed in a compacted earth dam, can be severe, regardless of the state of soil compaction, if the proper fluid environment is present.

CHRISTODOULOU, G. C., LEIMKUHLER, W. F., and IPPEN, A. T. 1974 (Jan). "Mathematical Models of the Massachusetts Bay; Part III, A Mathematical Model for the Dispersion of Suspended Sediments in Coastal Waters," Report No. 179, Massachusetts Institute of Technology, Department of Civil Engineering, Ralph M. Parsons, Laboratory for Water Resources and Hydrodynamics, Cambridge, Mass.

A three-dimensional analytical model is proposed for the description of the dispersion of fine suspended sediments in coastal waters. The model basically predicts the quasi-steady state sediment concentration as a function of space, tidal time, and the deposition pattern in the region surrounding a continuous vertical line source. It requires that the sediment settling velocities and the hydrodynamic features of the area, i.e., the net drift, the tidal velocities, and the dispersion coefficients, be known. Effects of wave action and vertical stratification are not explicitly considered. A separation of variables technique permits a rather independent treatment of the vertical and horizontal distributions; they are linked primarily through the decay factor, which represents the loss of material to the bottom.

The model is applied to a hypothetical dredging situation in Massachusetts Bay. Values for the hydrodynamic parameters were obtained from the analysis of field data collected during the past year. Laboratory experiments were carried out for the determination of settling rates of clays in seawater, in view of unknown flocculation factors. Stokes' law was considered adequate for silt and very fine sand.

The model results indicated very long and relatively narrow dispersion patterns, under the assumption of constant drift direction. The net drift and the sediment settling velocity seem to be the most important factors controlling the dispersion of fines in coastal waters.

COHEN, Y. 1983. "Microelectrode Studies of the Photosynthesis and O_2, H_2S, and pH Profiles of a Microbial Mat," Limnology and Oceanography, Vol 28, No. 6, pp 1062-1074.

The profiles of O_2, H_2S, and pH within a microbial mat of the hypersaline pond Solar Lake, Sinai, were measured by 2- to 200-μm-thick microelectrodes during diurnal and artificial light cycles. The oxygen concentration in the photic layer varied from a maximum of 1,400 μm during the day to 0 during the night. The pH in the same layer varied between 9.6 in the early afternoon and 7.7 in the early morning. Sulfide was not present in the photic zone during the day, but built up to about 50 μm during the night. The diffusion gradients of sulfide and oxygen were very steep, and the two compounds coexisted in a layer only 0.25 mm thick during the day. Diffusion flux calculations showed that the average turnover time of sulfide within this layer was 21 sec. The rapid turnover indicated that the oxidation of sulfide must be biologically mediated. Oxygenic photosynthesis was measured by a new oxygen microprofile method which accurately determines the vertical distribution of photosynthetic activity. There was no difference in the efficiency of photosynthesis between morning and afternoon. The photosynthetic efficiency of the whole mat was about fourfold higher at low light intensities, <120 μEinsteins m^{-2} sec^{-1}, than at high light intensities, 120-1,600 μEinsteins m^{-2} sec^{-1}. Anoxygenic photosynthesis within the mat was not quantitatively important.

COLE, P., and MILES, G. V. 1983. "Two-Dimensional Model of Mud Transport," Journal of Hydraulic Engineering, Vol 109, No. 1, pp 1-12.

A two-dimensional finite difference model is presented which models the transport of well-mixed cohesive sediments in estuaries and coastal waters. A description of each of the physical processes incorporated in the model is given. An erosion mechanism is not included explicitly because of the difficulties involved in a realistic formulation. Instead, areas of net deposition throughout a tidal cycle are identified, and rates of mud deposition within these areas are predicted. Two applications of the model to siltation studies are presented, involving different modes of operation of the model. In each case, field data in the form of bed core samples were available, so that the models could be both verified and calibrated. Under these circumstances, the model can be used to make useful engineering predictions such as projected dredging requirements in estuaries and ports.

COLEMAN, J. M. 1966. "Recent Coastal Sedimentation: Central Louisiana Coast," Series No. 17, Louisiana State University, Coastal Studies Institute, Baton Rouge, La.

The Recent near-surface sediments of Vermilion, Iberia, and St. Mary Parishes, Louisiana, may be divided into two types: those sediments which were deposited by now-abandoned Mississippi River distributaries and those carried alongshore and deposited at the delta margin. The oldest recognizable Recent Mississippi River delta, the Maringouin or Sale-Cypremort, was actively depositing sediments in this region approximately 4,600 years ago. During its development, quantities of fine-grained sediment were swept westward by longshore currents beyond the limits of the delta proper, blanketing the adjacent coast. Resulting mud flats caused coastal progradation, the dominant process of the marginal deltaic area. Immediately following the formation of mud flats, encroachment by salt-tolerant marsh vegetation began, and the process of blanket coastal peat formation was initiated. Later, a change in delta position caused a decrease in longshore sediment supply, and regional subsidence became dominant. Subsequent shoreline retreat under wave attack resulted in the formation of local beach ridges that were later stranded by another influx of sediments. Several similar cycles of sedimentation, marsh development, and beach ridge formation are found in the shallow subsurface. These cycles can be correlated with various changes in the Mississippi River delta position.

The physical, faunal, and floral properties obtained from a study of present-day surface sedimentary environments (natural levee, nearshore marine, mud flat, oyster reef, beach, marsh, brackish bay, lacustrine, and swamp) were used to interpret subsurface relationships and establish a stratigraphic section. Five laterally continuous peat horizons were identified in the subsurface, each marking a former marsh surface formed at approximately high tide level. These older marsh surfaces, now buried at depths ranging from 4 to 40 ft, indicate the positive change of level that has taken place since their formation. Abundant evidence for a stillstand in sea level during the past 2,000 to 5,000 years affords a fixed datum for differentiation between eustatic sea level rise and subsidence. The rate of subsidence in the study area is 0.24 ft per century. Using this rate, calculations reveal a eustatic sea level rise of approximately 23 ft in the interval from 7,000 to 3,650 years BP when stillstand was reached. There is no indication that sea level was higher than at present during the interval studied. Similar results were obtained by applying this method to published data on sea level changes in The Netherlands, Massachusetts, and Connecticut.

COLEMAN, N. L. No date. "Similitude of Velocity and Suspended Sediment Concentration Profiles," US Department of Agriculture, Sedimentation Laboratory, Oxford, Miss.

Flows laden with suspended sediment are common in natural streams and man-made channels. Sediment suspension and its interaction with velocity distribution in channel flow is of practical interest to the channel designer, who seeks to design stable channels with predictable flow and sediment transport capacity, and to the modeler, who seeks to simulate channel responses to diverse sediment and water inputs.

For expressing or predicting velocity profiles, both the law of the wall and the velocity defect law, which are derived for the case of classical boundary layer flow, are routinely adapted to open-channel flows of either clear water or water with suspended sediment. From the success of these adaptations it is evident that, for the velocity profile, the same nondimensional similitude terms are appropriate for both clear water and sediment-laden flows, at least for moderate sediment concentrations.

For expressing or predicting suspended sediment concentration profiles, the classical approach has been to integrate a differential equation for sediment diffusion using the assumption that the velocity profile is logarithmic over the entire depth of open-channel flow. In this treatment, the local concentration at a given elevation in the flow is referenced to an arbitrary reference level in order to integrate the sediment diffusion equation. The result is an unsatisfactory similitude (nondimensional) formulation for the sediment concentration profile. No clear idea of the appropriateness of the normalizing variable is given, and data do not in general collapse to one universal function.

A first step in obtaining a universal suspended sediment concentration profile function has been made by parallel integration of the momentum conservation equation for the velocity profile and the sediment diffusion equation for the concentration profile. This results in expressions for both velocity and concentration profiles in terms of the same or analogous normalizing variables.

COLLINS, M. B., and RIGLER, J. K. 1982 (Jun). "The Use of Settling Velocity in Defining the Initiation of Motion of Heavy Mineral Grains, Under Unidirectional Flow," Sedimentology, Vol 29, No. 3, pp 419-426.

The results of critical threshold experiments on four commonly occurring heavy minerals are described. The data are presented, in conjunction with comparable quartz data, using the nondimensional Shields' curve and the Movability Number U_*/w_s. The results indicate that critical shear stress for material of high density is overestimated by use of Shields' curve, under smooth boundary conditions. Grain settling velocity is found to be a good indicator for the critical shear stress for grains of a wide density range. A physical explanation for the results is proposed.

CONNOLLY, J. P., ARMSTRONG, N. E., and MIKSAD, R. W. 1983. "Adsorption of Hydrophobic Pollutants in Estuaries," Journal of Environmental Engineering, American Society of Civil Engineers, Vol 109, No. 1, pp 17-35.

Using Kepone as the test compound, the relation of sediment suspension to fate of hydrophobic pollutants through adsorption is examined. Adsorption experiments show rapid attainment of an equilibrium condition that is a linear function of dissolved Kepone concentration and an inverse nonlinear function of adsorbing solids concentration. An apparatus creating a one-dimensional distribution of suspended sediment over a sediment bed is used to experimentally simulate an estuarine tidal cycle during which the transfer of Kepone from the bed to water column is examined. A mathematical model of the adsorption and sediment resuspension process is used to analyze the experimental results. Resuspension and the variation of adsorption equilibrium with solids concentration are shown to be significant to the transfer. Adsorption kinetics are not significant because of the rapid approach to equilibrium.

CONOMOS, T. J., and PETERSON, D. H. 1976. "Suspended-Particle Transport and Circulation in San Francisco Bay: An Overview," US Department of the Interior, US Geological Survey, Water Resources Division, Virginia.

Differences in the relative magnitude and timing of wind stress and river inflow in the northern and southern reaches of San Francisco Bay create different sedimentary conditions. The northern reach is a partially to well mixed estuary receiving most of the total annual freshwater input ($840\ m^3\ sec^{-1}$) and suspended sediment input (4×10^6 metric tons) into the bay; more than 80 percent of the sediment is received during winter. Density-driven nontidal estuarine circulation ($\sim 5\ cm\ sec^{-1}$) maintains a turbidity maximum which changes seasonally in particle concentration (40 to $80\ mg\ \ell^{-1}$). Strong tidal currents ($\leq 225\ cm\ sec^{-1}$) and wind-generated waves resuspend sediment from the shallow bay floor; some of the riverborne sediment deposited during winter is resuspended during summer and transported landward to the turbidity maximum. Long-term sediment data (extrapolated from bathymetric charts) indicate that the northern reach is an effective sediment trap. In contrast, long-term sediment data suggest that the southern reach is experiencing net erosion. The southern reach receives little river inflow or riverborne suspended sediment, and the average nontidal circulation is weak ($\leq 2\ cm\ sec^{-1}$). The principal source of suspended sediment ($25\ mg\ \ell^{-1}$) in the southern reach is the shallow bay floor (average depth 6 m).

COOPER, J. A., NIELSON, H. L., WOGMAN, N. A. and PERKINS, R. W. 1975 (Jun). "Feasibility Study of In Situ Sediment Analysis by X-ray Fluorescence," Nuclear Technology, Vol 26, No. 2, pp 224-231.

It has been established that energy-dispersive X-ray fluorescence can provide in situ sediment analysis detectabilities that approach those attainable in the laboratory and that can be used to map the concentration of many heavy element pollutants in lakes, rivers, and estuaries. The method involves excitation with a ^{109}Cd radioisotopic source and analysis of the X-rays with a silicon-lithium detector housed in a solid-cryogen cryostat with a 0.005-in.-thick beryllium window. This system, with available technology, would be capable of providing analyses for about 13 elements (chromium, manganese, iron, nickel, copper, zinc, arsenic, bromine, rubidium, strontium, yttrium, zirconium, and lead) at their typical concentration levels and could provide lower limit values in the 5- to 20-ppm range for gold, mercury, selenium, germanium, and gallium in analysis times of about 4 min. A system using advanced excitation techniques should be capable of providing low ppm detectabilities in analysis times of 2 to 3 min. The concentration of cadmium could be determined at levels of about 20 ppm but would require a special excitation source. Various experimental arrangements were considered, and experimental results for simulated in situ analysis were obtained.

CRICKMORE, M. J. and AKED, R. F. 1975 (Sep). "Pump Samplers for Measuring Sand Transport in Tidal Waters," Conference Proceedings on Instrumentation in Oceanography, University College of North Wales, Bangor, Wales, 23-25 Sep 1975.

Field instrumentation for determining flow-depth profiles of water velocity and suspended solids is described. Attention is drawn to the advantages of using pump samplers to measure the concentration and size of sediment in suspension. Constraints on the design of suitable pumping systems and velocity sensors are discussed. The need to match system to particular working conditions is demonstrated by describing four rigs all developed to measure sediment transport but differing widely in form to meet the requirements of specific tidal situations.

CROAD, R. N. 1981 (Feb). "Physics of Erosion of Cohesive Soils," Ph.D. Dissertation, University of Auckland, Auckland, New Zealand.

Experiments with saturated kaolinite-, two Na-bentonite-, and Ca-bentonite-water systems are described in which the dependence of erosion rate $\dot{e}$ on the bed shear stress τ, temperature T, salinity, pH, ζ-potential, and sample consolidation pressure was studied. For the kaolinite and Ca-bentonite samples, the eroding pore water was the same; pH was varied using HCl or NaOH and salinity was varied using NaCl or $CaCl_2$, respectively, for each clay. For the Na-bentonites, distilled deionized water was used as the pore water; the pH of the eroding water was varied using HCl or NaOH and salinity was varied using NaCl. As an aid to the interpretation of the erosion experiments, rheological flow property experiments, electron microscopy studies, and electrophoresis measurements were also carried out on the clays.

The results indicate that the $\dot{e}$ versus τ curves for the clays studied form part of a general family of curves. The most general case, with increasing τ, is a $\partial^2\dot{e}/\partial\tau^2 < 0$ trend followed by a $\partial^2\dot{e}/\partial\tau^2 > 0$ trend. Either trend may predominate. Erosion appears to occur at all nonzero values of shear stress.

For increasing values of T the most general form of the $\dot{e}$ versus T curve appears to be a ∩-shaped trend merging into a U-shaped trend. Individual cases, however, may show only "window frame" views of the general trend.

Generally, the form of the $\dot{e}$ versus pH curve is similar to that of the ζ-potential versus pH curve for each soil. Erosion properties were found to be closely allied to the flow properties of suspensions of this clay. Relating to the kaolinite at low pH values, a weak negative dependence of $\dot{e}$ on consolidation pressure was discernible. At high pH values, however, a strong negative dependence of $\dot{e}$ on consolidation pressure was observed. For all clays investigated, a decrease in $\dot{e}$ with increasing salinity was observed.

A theoretical model of erosion was developed in which it is proposed that the entrainment of fragments of clay is caused by the negative pressure fluctuations which are associated with the turbulent "burst" cycle (the origin of turbulence in the flow). An analogy is drawn between the erosion process and processes which occur in chemical reactions. The resultant expression for $\dot{e}$ correctly predicts the observed $\dot{e}$ versus τ and $\dot{e}$ versus T trends.

CUSHMAN, J. H. 1984 (Nov). "On Unifying the Concepts of Scale, Instrumentation, and Stochastics in the Development of Multiphase Transport Theory," Water Resources Research, Vol 20, No. 11, pp 1668-1676.

A generalized theory of multiphase transport is presented which combines the concepts of scale, instrumentation, stochastics, and time series with the development of transport equations. By defining the filtering process as a convolution of a measure P with a field property ψ, the Fourier transform can be exploited to place plausible restrictions on an instrument in frequency space so as to make its measurement relevant to its physical environment. An ideal instrument is defined which filters out high-frequency noise (corresponding to short distances) and yet does not alter the structure of low frequencies. Using ideal instruments, lower frequency noise is successively filtered out in a multiscale, multiphase environment. Formulas are developed to relate the autocorrelation of a field property on one scale of motion to that on any other scale while taking into account the types of instruments used in the measuring process. An equation relating the integral scale on one scale of motion to the integral scale on any other scale of motion is developed. Power spectra are developed which relate spectra on different scales to the measuring instrument used. By successively applying filtering theorems, a hierarchy of multiscale transport equations is developed. Filtered properties in the transport equations are mass averages. Different properties are allowed to be measured by different instruments and different instruments are allowed on different scales of motion and for different phases. The concept of a wide-sense stationary, ergodic process is introduced to develop mass average autocorrelations and spectra over scales of motion as a function of measuring devices.

CUSTER, E. S., JR., and INGRAM, R. L. 1974 (Aug). "Influence of Sedimentary Processes on Grain Size Distribution Curves and Bottom Sediments in the Sounds and Estuaries of North Carolina," Sea Grant Publication UNC-SG-74-13, University of North Carolina, Department of Geology, Chapel Hill, N.C.

Analysis of 142 sediment samples from Pamlico Sound and associated estuaries indicates that grain size distributions reflect (a) the proportion of sediment transported by suspension, traction, and saltation; (b) the grain size limits for each population; and (c) the type of energy source, waves or currents. Sediment finer than 3.3 ϕ was transported in suspension. Sediments ranging in grain size from 3.3 ϕ to 1.5 ϕ were transported by saltation. Sediments between 1.5 ϕ and 0.8 ϕ were transported by either saltation or traction. Sediments coarser than 0.8 ϕ were usually transported as the traction load.

The sorting of the saltation populations, the coarseness of the saltation-traction truncation point, and the amount of suspension material are indicative of the energy source. Wave action is indicated by the presence of well-sorted saltation populations. Current action is indicated by less well-sorted to moderately sorted saltation populations.

D

DALTON, F. N., HERKELRATH, W. N., RAWLINS, D. S., and RHOADES, J. D. 1984 (Jun). "Time-Domain Reflectometry: Simultaneous Measurement of Soil Water Content and Electrical Conductivity with a Single Probe," Science, Vol 224, pp 989-990.

Two parallel metallic rods were used as a wave guide to measure the dielectric constant and electrical conductivity of soils having different electrical conductivities but the same water content. Measurements showed that the two parameters were sufficiently independent to permit simultaneous determinations of water content and bulk electrical conductivity.

D'ANGLEJAN, B. 1980 (Apr). "Effects of Seasonal Changes on the Sedimentary Regime of a Subarctic Estuary, Rupert Bay (Canada)," Sedimentary Geology, Vol 26, No. 1/3, pp 51-68.

Rupert Bay is a large (875 km^2), shallow estuarine embayment opening in James Bay north of Hudson Bay, Canada. Three large rivers with a combined annual mean discharge of 2,350 m^3/sec converge into the bay. Due to ice unloading and crustal readjustment, at a current rate of 1 m/100 years, these rivers have excavated their channels into marine sediments of the early post-glacial Tyrrell Sea invasion. These provide the main source of the poorly sorted silty clays forming the present deposits.

Sediment transport and deposition are influenced by strong seasonal fluctuations in climate, with a continuous ice cover for nearly 6 months of the year, a rapid breakup, and spring discharges which are as much as 16 times the yearly minima.

During the open season, high turbidity prevails with a pronounced streakiness in the flow direction and stable fronts at the boundaries of the river plumes. Both the turbulence by local wind waves and tidal action hinder deposition. Determinations of the suspended load and velocity at tidal stations indicate that conditions are met for seaward tidal flushing of the sediments brought in by the rivers. Under ice-covered conditions, there is a pronounced decrease of the suspended matter concentrations in the reduced volume of the bay, suggesting that settling occurs below the ice cover, the winter deposits being largely returned to the water column in the following spring.

Low present depositional rates are confirmed by measurements of the ^{137}Cs activity in the surface deposits. On a longer term basis, crustal rebound maintains a slight regional uplift which forms entrenchment of the river channels as well as slow progradation of the supratidal marshes.

D'ANGLEJAN, B., and INGRAM, R. G. 1976. "Time-depth Variations in Tidal Flux of Suspended Matter in the Saint Lawrence Estuary," Estuarine and Coastal Marine Science, Vol 4, pp 401-416.

An investigation of the factors controlling the variability of suspended matter concentration at different sites in the St. Lawrence River estuary indicates that advection is much more important than local resuspension over the semidiurnal tidal cycle. This finding is in contrast to that observed in shallower estuaries. All stations exhibit middepth maxima in suspended matter concentration. The occurrence of these maxima corresponds approximately to the end of the ebb flow. Variations from this pattern are attributable to large cross-channel flow. Calculated values of suspended matter flux are used to explain the time and depth variations of suspended matter concentrations.

DASH, U. 1968. "Erosive Behavior of Cohesive Soils," Ph.D. Dissertation, Purdue University, West Lafayette, Ind.

The study investigated the influence of soil variables such as soil type, clay percentage, and water content on the erosion behavior of cohesive soils.

Commercial clays (Grundite and Edgar Plastic Kaolin) were used and were mixed with Ottawa sand to achieve different clay percentages. Erosion testing was undertaken on saturated consolidated samples in a vertical jet apparatus and on nearly saturated compacted samples in a flume section. Soil resistance was evaluated by means of drained uniaxial tensile testing.

Based on dimensional analysis and energy considerations, a model of behavior relating hydraulic and soil variables has been developed. Experimental results are compared with the theory.

A number of principal and general conclusions have been reached, subject to the types of experimentation and the number and level of variables investigated.

DeFLAUN, M. F., and MAYER, L. M. 1983. "Relationships Between Bacteria and Grain Surfaces in Intertidal Sediments," Limnology and Oceanography, Vol 28, No. 5, pp 873-881.

Seasonal changes in total bacterial numbers and their associated mucus coatings in surficial sediments were examined. Bacterial numbers followed the temperature cycle, with highest numbers in summer. The specific surface areas of the sediments were measured rather than inferred from other granulometric properties; bacterial numbers were proportional to surface areas only for sample suites collected at the same time. Bacteria inhabited shallow depressions on sand and silt grains; they were not found on grains smaller than about 10 μm or inside smaller pores like those on weathered feldspar grains. Mucus coatings also followed a seasonal cycle, increasing in abundance and coalescence from spring into summer. These coatings accumulated clay grains, suggesting that the relationship of bacteria to surface area may be due to bacterial control of surface area rather than the reverse. Organic carbon concentrations in grain-size separates of these sediments increased with decreasing size until the fine silt fraction, and decreased in the clay fraction; it is not clear, however, whether this trend is a result or a cause of bacterial colonization patterns.

DeGROOT, A. J. 1964. "Origin and Transport of Mud (Fraction <16 Microns) in Coastal Waters from the Western Scheldt to the Danish Frontier," Developments in Sedimentology, Deltaic and Shallow Marine Deposits, Proceedings, Sixth International Sedimentological Congress, Vol 1, Elsevier Publishing Co., Amsterdam, pp 93-100.

To determine the contents and character of manganese compounds in Holocene deposits (fractions <16 μ) along the North Sea coast of Holland and Germany, several thousands of analyses have been made. It was found, among other things, that the manganese content is very variable, owing to post-depositional migrations. When this influence is allowed for, regional differences appear to exist, which can be interpreted as the result of primary differences in manganese content of the source material. Using manganese as a tracer, the following conclusions can be drawn about the origin of the mud and the directions of transport along the coast.

The mud in the Eastern and Western Scheldt is supplied for a small part by the river Scheldt. The river influence is strongest in the eastern part of the Western Scheldt. Most of the mud deposited in these two estuaries is brought in from the North Sea. Originally it probably comes from the British Channel.

The mud of the rivers Rhine and Meuse, which is not deposited in the estuaries, is carried in a northeasterly direction, along the coast of South and North Holland and is partly deposited in the Wadden Sea.

Supply of mud by the river Ems is an important factor for the sedimentation in the Dollard. The contribution of river material is seen to diminish when going along the Dollard shores from the mouth of the Ems via the southern part to the Punt van Reide.

Deposition along the western shores of Schleswig-Holstein takes place under influence of the supply of mud by the river Elbe and by erosion of older Holocene deposits on the flats in front of the shores of Dithmarschen and North Friesland.

The supply of mud by the river Thames has no visible significance on the composition of the fine-grained sediments along the coasts of the continent.

DELFT HYDRAULICS LABORATORY. 1974 (Feb). Hydro Delft, No. 34, Delft, The Netherlands.

In 1962, Dr. A. J. de Groot, at that time scientific coworker at the Institute for Soil Fertility, dealing with the detection of the origin of fine sediments along the Dutch and German coastline, focussed attention in his thesis on new approaches to the determination of silt migration.

As the Delft Hydraulics Laboratory wished to cooperate with the Institute so that its knowledge and facilities could be incorporated in investigations where clayey silts and their displacement by flowing water were the main object, this automatically included the study of sedimentation characteristics, because these depend on physical and chemical conditions.

This intensification of the knowledge of the silt and clay properties and refinement in their analysis was of real importance in establishing migration patterns. It developed into the preparation of natural silt artificially loaded with rare elements and using this in bulk as a tracer material to detect the natural processes. As the samples were investigated by activation analysis, it provided a safe and precise method.

This development in its turn served as a base for detailed studies on the behavior of silts and clays, as seen in their capacity to absorb heavy metals and chlorinated aliphatic hydrocarbons and to act as a vehicle for transportation by the flowing water until settlement. Mobilization of those additives by changing water conditions, as occurs in estuaries and coastal regions, makes this knowledge in determining the impact on biological processes of the utmost importance to detect the processes in the environment. A detailed survey of the field of work is presented in the articles, which also clearly illustrate the need for this effort.

DELL, C. C., and SINHA, J. 1966 (Jun). "Experimental Study of the Behaviour of Flocculated Clays in Thickening," Institution of Mining and Metallurgy, Transactions, Section C, Vol 75, No. 715, pp c139-c146.

The sedimentation behavior of flocculated clay has been studied by measuring the vertical distribution of solids during a batch sedimentation test by means of rubber diaphragms. The flow-density structure of the suspension was then determined by graphical methods.

It is shown that, with this material, solids concentration is closely related to the pressure transmitted through the solid phase--not to the local settling velocity. Rate of formation of pulp of a given density and ultimate pulp density both depend upon the weight of solids per unit area and are affected by initial concentration and height of column only inasmuch as those factors affect the weight of solids per unit area. The throughput capacity of a thickener thus depends upon both area and depth when flocculated clay is being treated.

DHAMOTHARAN, S., GULLIVER, J. S., and STEFAN, H. G. 1981 (Aug). "Unsteady One-Dimensional Settling of Suspended Sediment," Water Resources Research, Vol 17, No. 4, pp 1125-1132.

A one-dimensional, unsteady numerical model for the prediction of the vertical distribution of suspended sediment concentration and rate of suspended sediment deposition in water stirred uniformly has been developed. The model is derived from the convective-diffusive transport equation and uses a fully implicit, exponential finite difference scheme. The model is unconditionally stable regardless of vertical diffusivities and particle fall velocities. Such a model previously has not been given in the sedimentation literature and is of interest for theory and applications. A generic study of vertical suspended sediment profiles and trap efficiencies has been made. The results, presented in dimensionless form, cover Peclet numbers Vh/D from zero to infinity. V is the particle fall velocity, h is the water depth, and D is the mean vertical exchange coefficient. In studies of suspended sediment behavior, the parameters V and D are often unknown or not well determined. The generic results generated show what kind of variations in suspended sediment concentrations and trap efficiencies can be expected with different values of V and D. Sediment deposition is shown to occur through downward frontal movement when Vh/D is large (≥ 20) and through columnar precipitation when Vh/D is small (≤ 0.2). Residence time is shown theoretically to be far more important for estimates of sediment deposition rate than turbulence. This is in agreement with empirical findings for reservoir trap efficiency.

DIETRICH, W. E. 1982. "Settling Velocity of Natural Particles," Water Resources Research, Vol 18, No. 6, pp 1615-1626.

Data from fourteen previous experimental studies were used to develop an empirical equation that accounts for the effects of size, density, shape, and roundness on the settling velocity of natural sediment. This analysis was done in terms of four nondimensional parameters, namely, the dimensionless nominal diameter D_*, the dimensionless settling velocity W_*, the Corey shape factor, and the Powers roundness index. For high D_* (large or dense particles), changes in roundness and shape factor have similar maghitude effects on settling velocity. Roundness varies much less for naturally occurring grains, however, and hence is a less important control than shape. For a typical coarse sand with a Powers roundness of 3.5 and a Corey shape factor of 0.7, the settling velocity is about 0.68 that of a sphere of the same D_*, with shape and roundness effects contributing about equally to the settling velocity reduction. At low D_* the reduction in settling velocity due to either shape or roundness is much less. Moreover, at low D_*, low roundness causes a greater decrease in settling velocity at low shape factor values than at high shape factor values. This appears to be due to the increased surface drag on the flatter grains.

DIONNE, J. C. 1973 (Sep). "Monroes: A Type of So-Called Mud Volcanoes in Tidal Flats," Journal of Sedimentary Petrology, Vol 43, No. 3, pp 848-856.

Small mud mounds, here called monroes, occur in tidal flats of the St. Lawrence estuary, Quebec, Canada. They were observed during break-up at Montmagny, 65 km NE of Quebec City, and at a few other localities. They occur generally in groups and occasionally in isolation in relatively soft mud, have a rounded conical shape with occasionally a nipple at the top, steep slopes (40° to 65°), and are 5 to 25 cm in diameter, and 5 to 20 cm high. They develop under the icefoot as a result of load pressures which expel air and possibly also water trapped under surficial soft mud layer and thin ice laminae during icefoot formation, in late fall. They characterize mud tidal flats of cold regions.

DIONNE, J. C. 1971. "Polygonal Patterns in Muddy Tidal Flats," Journal of Sedimentary Petrology, Vol 41, No. 3, pp 838-839.

At spring time, polygonal mud ridges develop in muddy tidal flats along the south shore of the middle St. Lawrence estuary, Quebec. They result from the squeezing of soft mud into the icefoot tidal cracks under load pressure related to tidal movements.

DIONNE, J. C. 1969 (Sep). "Tidal Flat Erosion by Ice at La Pocatière, St. Lawrence Estuary," Journal of Sedimentary Petrology, Vol 39, No. 3, pp 1174-1181.

The tidal flat areas of the Middle St. Lawrence estuary are severely eroded by shore ice. Grooves parallel or perpendicular to the shoreline, measuring 30 to 80 cm wide, 20 to 35 cm deep, and 1500 to 2000 m long, and circular or subcircular basins up to 2 m in diameter and 20 to 40 cm deep are produced every spring by ice blocks that plough the surface and greatly disturb the sediments.

DIXIT, J. G. 1982. "Resuspension Potential of Deposited Kaolinite Beds," <u>M.S. Thesis,</u> University of Florida, Gainesville, Fla.

Review of literature indicated that it was necessary to treat the phenomenon of the resuspension potential of cohesive sediment bed considering the influence of (a) clay composition (type and amount), (b) organic content, (c) chemical composition of pore and eroding fluids, (d) temperature of suspension, and (e) bed history (i.e., mode of bed formation).

The objective of the present studies was to find the erosion of cohesive sediment bed in response to the applied shear stress for a single bed history of the flow-deposited bed. The experiments were conducted in the recirculating flume using kaolinite equilibrated with water. The consolidation period was varied in order to investigate influence of consolidation on the depth-variation of the critical stress and the rate of erosion. The bed shear stress was applied instantaneously and was increased in steps with constant duration each time-step. Two different series of tests were conducted, settling on the value of normalized incremental shear stress, $\Delta\tau_i$.

Series A: Tests with $\Delta\tau_i \approx 0.5$. The tests were conducted with the following consolidation periods: 2, 5, 11, 24, 48, 72, 96, 144, and 240 hours.

Series B: Four tests were conducted for the consolidation period of 5 hours with variable $\Delta\tau_i$. $\Delta\tau_i$ values were approximately 0.20, 0.50, 0.66, and 0.80.

DIXIT, J. G., MEHTA, A. J., and PARTHENIADES, E. 1982 (Aug). "Redepositional Properties of Cohesive Sediments Deposited in a Long Flume," UFL/COEL-82/002, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, Fla.

Results from fine sediment deposition studies conducted in a 100-m-long flume at the US Army Engineer Waterways Experiment Station in Vicksburg, Mississippi, are herewith reported. The primary objective of these studies was to examine the sorting effect on the depositional parameters of cohesive sediments as the latter deposit along a straight channel. Three tests using kaolinite and a fourth using mud from the Atchafalaya Bay, Louisiana, were conducted in the 100-m flume under steady turbulent flows. In each test suspended sediment was allowed to deposit under a specific discharge, while maintaining a near-constant depth of flow. The undeposited portion of the sediment was washed out, leaving a sorted deposit in the flume. Sediment accumulated in each 12-m reach of the flume bed was next resuspended in a specially designed annular rotating flume and was allowed to deposit under a constant bed shear stress.

The rates of deposition in the annular flume were found to follow a log-normal law derived previously by Partheniades, Mehta, and others using a wide range of cohesive sediments, each containing the entire naturally occurring particle size distribution. The degree of deposition was also found to depend upon the bed shear stress. The functional form of this relationship was determined to be analogous to that found by Mehta and Partheniades. While the latter found this relationship to be log-normal as well, in the present investigation a log-log expression was obtained. This difference is attributed to the influence of sorting in the 100-m flume. The dependence of the parameters which characterize the expressions for the rate and the degree of deposition on flow conditions during deposition in the 100-m flume and on the type of sediment have been examined. Settling velocities of the sediments have been estimated. An explanation of the observed behavior of sediment transport and deposition in terms of the sorting mechanism in the 100-m flume is given.

DOBBINS, W. E. 1944. "Effect of Turbulence on Sedimentation," Transactions, American Society of Civil Engineers, Vol 109, Paper No. 2218, pp 629-678.

The basic theory of turbulent flow has been applied successfully to explain the observed vertical distribution of suspended matter in streams in which the specified load is in equilibrium with the bed material. This paper presents the results of studies made in an effort to extend the theory to explain the concentration changes in a stream or settling basin under nonequilibrium conditions. The general differential equation expressing the concentration changes during turbulent sedimentation in an infinitely wide stream is derived, and the complete solution for a certain simplified case is presented. Evidence of the turbidity of this solution is provided by the results of experiments which are described herein.

D'OLIER, B. 1979. "Side-Scan Sonar and Reflection Seismic Profiling," Estuarine Hydrography and Sedimentation, K. R. Dyer, ed., pp 57-86, Cambridge University Press, Cambridge, England.

In the latter half of the nineteenth century and in the early years of the twentieth, a great deal of fundamental research into the elastic properties of various media was carried out. In particular, experiments demonstrated the ability of water to conduct mechanical vibrations, and showed that this energy will be reflected or refracted at any boundary separating two media of contrasting properties, e.g., seawater and the sea-bed--sediment interface. R. A. Fessenden in 1912 was the first person to apply these principles when he built an apparatus to measure the time taken for sound waves to travel to the sea-bed and back, and later developed it for "secret" communication underwater from ship to ship using Morse Code.

From experience gathered during the First World War arose the need for increased accuracy of water-depth measurement and, closely coupled with this aim, a means of detecting objects underwater, be they wrecks, shoals, rock bars, fish, or submarines. During the 1920's, the first practical echo-sounder using high-frequency sound waves was produced. It was soon realized that by turning the transducer into the inclined or even the horizontal mode an effective means of detecting underwater objects had been created. Development continued, resulting in equipment used so effectively to detect submarines during the Second World War. This equipment was called ASDIC, an acronym for Anti (Allied) Submarine Detection Investigation Committee. Many ASDIC operators soon realized that different sections of sea-bed over which they were passing produced return signals of differing intensity. This observation was followed by work expressly aimed at mapping the sediments and features of the sea-floor. In 1956 Knott & Hersey reported on work involving a pair of towed transducers set to examine the sea-floor on both sides of a ship at the same time. The first purpose-built geological side-scan sonar (Sound Navigation and Ranging) was manufactured to a British National Institute of Oceanography design in 1960 and a version was made available commercially by Kelvin Hughes Ltd. in 1962. Since then, development has been extremely rapid and the side-scan sonar has become a standard and essential tool for the geological study of any lacustrine, fluvial, estuarine, or marine environment.

DRAKE, D. E., HATCHER, P. G., and KELLER, G. H. 1978. "Suspended Particulate Matter and Mud Deposition in Upper Hudson Submarine Canyon," Sedimentation in Submarine Canyons, Fans, and Trenches, D. J. Stanley and G. Kelling, eds., Chapter 3, pp 33-41, Dowden, Hutchinson & Ross, Inc., Stroudsburg, Penn.

Concentrations of suspended matter of 2,210 to 3,440 μg/ℓ were present near the bottom at depths of 200 m to 450 m in Hudson Canyon during March 1974. The suspended matter was mostly inorganic mineral grains, and two samples contained significant amounts of coarse silt (10 to 20 percent) and very fine sand (5 to 10 percent). Suspended matter concentrations near the sea floor declined both shoreward and seaward from the head of the canyon; concentrations of about 600 μg/ℓ were measured at 893 m in the canyon, and values of 400-600 μg/ℓ were present over the surrounding shelf.

Current measurements at 3 m above bottom in the canyon head (223 m) revealed reversing flows of tidal period with peak speeds of 25 to 35 cm/sec and a strong net downcanyon component which averaged about 8 cm/sec over a 6-day period. The combined suspended matter and current velocity data indicate important resuspension of the fine-grained components of the canyon head sediments followed by transport to deeper water along the axis of the canyon.

A 5-m piston core recovered in the canyon axis at 430 m contained an apparently continuous record of silt and clay accumulation. Radiocarbon dates at three levels in the core suggest a mean sedimentation rate of about 80 cm/10^3 years over the past 6,300 years. If this single core is representative of the sedimentation regime in this part of Hudson Canyon, the implication is that much of the sediment resuspended in the head of the canyon (<300 m depths) is deposited before moving far downcanyon. Furthermore, the textural character of the core sediments implies that vigorous bottom scour has been infrequent over the past several thousand years except in the shallowest portions of the canyon. Sediment transport by turbidity currents of high velocity appears to be unimportant in this canyon at the present time.

DUKE, C. M. 1961 (Feb). "Shoaling of the Lower Hudson River," Journal, Waterways and Harbors Division, American Society of Civil Engineers, Vol 87, No. WW1, pp 29-45.

A major item of maintenance, and a deterrent to the full use of the Hudson River frontage for maritime purposes, is the heavy shoaling which occurs in the channel and adjacent slips of the lower estuary. There is discussed herein the progress of investigations to find a solution to this problem. These include the sources of sedimentation, the characteristics of the fresh and salt water components of flow within the estuary, the quantity of shoaling which occurs, and the fundamental principles affecting the sedimentation process. Because of the non-analytic character of the complex factors involved in this problem, two hydraulic models are being used to prove a number of possible solutions. The first model reproduces the entire New York Harbor and the Hudson River up to the normal limit of salt-water intrusion at Poughkeepsie, NY (a distance of 100 miles), has a horizontal scale of 1:100, and has a vertical scale of 1:100. A second enlarged model reproducing the lower Hudson River from about 1 mile upstream of the Battery to about 1 mile downstream of the George Washington Bridge (a distance of about 9 miles) has a horizontal scale of 1:300 and a vertical scale of 1:100. This model is designed to study the local slip shoaling. Although model studies and analysis of results have not yet reached a point where it can be said that a final solution has been found to the problem (as of 1960), interim conclusions are presented on the results of some twenty plans and variations tested. These include the use of sedimentation basins, the realignment of the deep-water channel by fills and dikes, and the closure of flow from one of the several component waterways.

DUNN, I. S. 1959 (Jun). "Tractive Resistance of Cohesive Channels," Journal, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 85, No. SM3, pp 1-24.

A method of estimating the tractive resistance of cohesive channel beds is proposed. The method is based on information obtained from simple soil tests (Atterberg Limits, Particle Size Analysis, Vane Borer Tests). The study was made for soil taken from cohesive channels in Colorado, Nebraska, and Wyoming.

DYER, K. R. 1979. "Estuaries and Estuarine Sedimentation," Estuarine Hydrography and Sedimentation, K. R. Dyer, ed., Chapter 1, pp 1-18, Cambridge University Press, Cambridge, England.

An estuary can be defined as a 'semi-enclosed and coastal body of water which has a free connection with the open sea and within which sea water is measurably diluted with fresh water derived from land drainage.' Thus, the combination of river discharge and precipitation exceeds the loss of water due to evaporation. There is another class of estuaries where the evaporation exceeds runoff plus precipitation. These are hypersaline lagoons. They have been termed negative estuaries, in contrast to the positive estuaries defined above. The same techniques of surveying and analysis are suitable for both types of estuary, but because most estuaries are positive ones, the emphasis will be placed on those.

Estuaries are very important even though their area is only a small proportion of the total world's surface. Because of their fertile waters, sheltered anchorages, and the navigational access they provide to a broad hinterland, estuaries have been the main centers of man's development. However, the promotion of trade and industry has led to large-scale alteration of the natural balance within estuaries by alteration of their topography, making for easier navigation for larger ships, and large-scale pollution, as a result of industrialization and population increases. Deforestation of the land leads to increased runoff from the land, increased flashiness of the discharge, and increased sediment load in the rivers. Building and paving of large areas also produces a quick response of runoff to rainfall and increased sediment load. These effects may be controlled by the building of dams and may be reduced by the removal of river water for industrial and household use. However, control of river flow will alter the natural tendency for rivers to flush sediments out of their estuaries and consequently may aggravate shoaling problems.

The prediction of dredging is based either on constructing hydraulic models or on mathematical models, into which the expected alternations can be fitted. For a fixed-bed hydraulic model, the topography of the estuary bed needs to be known accurately, and for a mobile-bed model, the distribution and hydraulic characteristics of the sediment as well. For both, a simple tidal curve is normally simulated at the open-sea end of the model and the roughness of the bed arbitrarily altered until the tidal curve and the flow velocities at a number of points within the estuary are faithfully reproduced. For mathematical models, less precise topographic information is required, but more complete descriptions of the velocity and density fields and of the tidal elevations are needed. In all cases, however, the models are only as good as the field data upon which their characteristics are based. Because the collection of the field data is such a demanding and expensive operation, it is necessary to be fully aware of the errors and drawbacks in the instruments and measuring techniques.

DYER, K. R. 1973. Estuaries: A Physical Introduction, John Wiley & Sons, London.

The interaction of fresh and salt water provides a circulation of water and mixing processes that are driven by the density differences between the two waters. The density of sea water depends on both the salinity and temperature, but in estuaries the salinity range is large and the temperature range is generally small. Consequently, temperature has a relatively small influence on the density and there is little information published on temperature fluctuations in estuaries. One can visualize estuaries, however, where temperature could be a dominant factor at times. Many tropical estuaries have little river flow entering them during the hot season. Surface heating could then provide sufficient density difference between the estuary and the sea to maintain a gravitational circulation. Because of the diurnal variation of temperature, however, these effects would be transitory. In many fjords there is no river discharge in winter and surface cooling is intense. The surface waters can then become more dense than those at depth and will tend to sink. This vertical circulation phenomenon is known as thermohaline convection. The effects of temperature, therefore, must not be forgotten.

Estuaries are formed in the narrow boundary zone between the sea and the land and their life is generally short. Their form and extent are being constantly altered by erosion and deposition of sediment, and drastic effects are caused by a small raising or lowering of sea level. These sea-level alterations may be eustatic, variations in the volume of water in the oceans, or isostatic, variations in the level of the land. In the recent geological past, there have been very large eustatic changes in sea level. About 18,000 years ago, the sea level stood about 100 m below its present level, the water being locked up in extensive continental ice sheets.

E

EATON, P. A., and HOHMANN, G. W. 1984. "The Influence of a Conductive Host on Two-Dimensional Borehole Transient Electromagnetic Responses," Geophysicists, Vol 49, No. 7, pp 861-869.

Transient borehole electromagnetic (EM) responses of two-dimensional (2-D) models using a direct and explicit finite-difference algorithm were computed. The program computes the secondary electric field which is defined as the difference between the total field and the primary (half-space) field. The time derivative of the vertical magnetic field in a borehole is computed by numerical differentiation of the total electric field. These models consist of a thin horizontal conductor with a finite width, embedded in a conductive half-space. Dual line sources energized by a step-function current lie on the surface of the half-space and simulate the long sides of a large rectangular loop.

Numerical results substantiate several important features of the transient impulse response of such models. The peak response of the target is attenuated as the resistivity of the host decreases. A sign reversal in the secondary electric field occurs later in time as the resistivity of the host decreases. The peak response and the onset of late-time behavior are delayed in time as well. Secondary responses for models with different host resistivities (10 to 1000 Ω-m) are approximately the same at late time. If the target is less conductive, the effects of the host, i.e., the attenuation and time delay, are less. It is readily apparent that there exists a time window within which the target's response is at a maximum relative to the half-space response. At late time the shape of the borehole anomaly due to a thin conductive 2-D target appears to be independent of the conductivity of the host. The late-time secondary decay of the target is neither exponential nor power law, and a time constant computed from the slope of a log-linear decay curve at late time may be much larger than the actual value for the same target in free space.

EDRINGTON, T. S., and CALLOWAY, T. M. 1984 (Mar). "Sound Speed and Attenuation Measurements in Gassy Sediments in the Gulf of Mexico," Geophysics, Vol 49, No. 3, pp 297-299.

The speed and attenuation of sound in gassy marine sediments in the Mississippi delta area have been measured by means of small (1 to 500 mg) explosive charges buried 30 m below the mud line. The respective values obtained were 800 m/sec and 1.4 dB/kHz-m. Effective gas content was estimated to be approximately 0.06 percent.

EDZWALD, J. K., and O'MELIA, C. R. 1975. "Clay Distributions in Recent Estuarine Sediments," Clays & Clays Minerals, Journal, Clay Minerals Society, Vol 23, No. 1, pp 39-44.

The distribution of clay minerals in Recent sediments can be explained by the relative stability of the clays. The rates of particle aggregation for three clays were determined in the laboratory in synthetic estuarine solutions; from the kinetic studies stability values were calculated. The results indicate that illite is more stable than kaolinite which is more stable than montmorillonite. The distribution of the clays in the Pamlico River estuary can be explained on the basis of relative clay stability where kaolinite which aggregates rapidly (relatively unstable clay) is found upstream of illite.

EDZWALD, J. K. 1972. "Coagulation in Estuaries," Publication No. UNC-SG-72-06, University of North Carolina, Chapel Hill, NC.

A conceptual model describing the coagulation of clay minerals in estuaries has been proposed and tested. Conceptually it was postulated that clay suspensions are destabilized by compression of the electrical double layer when these suspensions are transported from fresh waters into estuaries. Operationally, it was postulated that the stability factor α depends on the chemistry of the system.

The coagulation rates of three clay minerals (kaolinite, illite, and montmorillonite) were determined in the laboratory in solutions at various ionic strengths. In addition, the coagulation rates of selected sediments collected from the Pamlico estuary of North Carolina were determined. Stability values α were evaluated from the kinetic coagulation data.

The coagulation kinetic data for the three clay minerals indicated an improvement in particle destabilization with increasing ionic strength (salinity). The stability factor was observed to depend on the type of clay mineral, the ionic strength of the solution, and the composition of the destabilizing solution (type of counter-ions). The stability of the three clays is as follows: Illite > Kaolinite > Montmorillonite. These results support the hypotheses that the mechanism of particle destabilization is double layer compression and that the stability factor α depends on the solution chemistry.

The composition of the clay fraction of sediments collected from the Pamlico estuary was determined by X-ray diffraction. Kaolinite was found as the dominant clay in the upper end of the estuary and decreased toward the mouth. Illite was found to occur in minor amounts in the upper end and increased toward the mouth. Montmorillonite was present in minor amounts and chlorite and a chlorite-like intergrade clay comprised the remainder of the clay fraction. The results of coagulation rate studies using Pamlico sediments indicated that the upstream sediments are relatively unstable (higher α values) as compared to the downstream sediments. The distribution of kaolinite and illite is explained by coagulation in which the least stable clays (higher α values) are deposited upstream of more stable clays.

EDZWALD, J. K., UPCHURCH, J. B., O'MELIA, C. R. 1974 (Jan). "Coagulation in Estuaries," Environmental Science and Technology, Vol 8, No. 1, pp 58-63.

Considerable attention has been devoted to the hydrodynamic and physical factors affecting the deposition of suspended materials in estuaries, but little research has been concerned with the role of chemical parameters. In this paper the aggregation of colloidal suspensions is examined with the purpose of elucidating the chemistry of this process.

This paper is divided into three sections. First, results are presented of coagulation rate studies conducted in the laboratory using three different clays. Second, the distribution of clays in the sediments of the Pamlico River estuary is examined with respect to coagulation kinetics. Finally, a discussion of the laboratory and Pamlico sections is presented.

EGOLF, E. B., and McCABE, W. L. 1937. "Rate of Sedimentation of Flocculated Particles," American Institute of Chemical Engineers, Vol 33, pp 620-640.

Since 1851, when Stokes put forth his equation describing the fall of a sphere in a fluid medium, work on sedimentation has progressed in several directions. Physical chemists have worked on the problem and its relation to colloid chemistry. Most of their work has been done on dispersed particles at rather low concentrations and in small-sized containers. Mining engineers have worked on it in connection with ore slimes. Their interests are more allied to those of the chemical engineer, and usually the work has been done with flocculated material on a larger scale. Robinson has offered an equation covering the rate of fall of a suspension, but it has been found limited to a suspension of high concentration. No formula is available which, given the initial height and concentration of a suspension of flocculated particles and the viscosity of the medium, will allow the prediction of the height of the suspension at any subsequent time. The development of such a formulation was the purpose of the present work.

The sedimentation of flocculated particles was studied using five different materials, (a) silica particles 16 μm in radius, (b) silica particles 5 μm in radius, (c) lead chromate, (d) zinc oxide, and (e) ferric oxide. The temperatures varied from 20° to 40° C., and the initial heights of the suspensions from 12.5 to 61.7 cm. The concentrations varied from the point where the suspension no longer settled with a sharp line up to the point where free settling was no longer exhibited.

EINSTEIN, H. A. 1941. "The Viscosity of Highly Concentrated Underflows and Its Influence on Mixing," American Geophysical Union Transactions, Papers, pp 597-603.

The viscosity of a clay suspension is measured for varying degrees of concentration and flocculation and the results interpreted as a possible explanation of the behavior of underflows of water, with high clay concentration, through reservoirs.

EINSTEIN, H. A., and KRONE, R. B. 1961 (Mar). "Estuarial Sediment Transport Patterns," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 87, No. HY2, pp 51-59.

The sediment deposits most characteristic of estuaries are muds which contain a large percentage of clays. These clays give the mud its particular qualities. The transport of these muds is largely determined by flocculation characteristic of suspended clays. The flocculation process is described and analyzed. The process of deposition and scour of the bed of these sediments is also described. All of these processes are finally combined in a description of the process of shoaling in Mare Island Strait, an artificially deepened side arm of San Francisco Bay.

EINSTEIN, H. A., and KRONE, R. B. 1962 (Apr). "Experiments to Determine Modes of Cohesive Sediment Transport in Salt Water," Journal of Geophysical Research, Vol 67, No. 4, pp 1451-1461.

Laboratory measurements were made on properties of clay sediments from San Francisco Bay, in conjunction with field measurements, to ascertain the modes of transport and deposition existing in the bay. Laboratory measurements of sediment suspensions, settling rates, rheological properties, and deposition from flowing water showed a dependence of the mode of transport on the suspended sediment concentration and on flocculation kinetics. These qualitative relations are supported by tracer observations of sediment transport processes in the bay.

ENGELUND, F., and ZHAOHUI, W. 1984 (Mar). "Instability of Hyperconcentrated Flow," Journal of Hydraulic Engineering, American Society of Civil Engineers, Vol 110, No. 3, pp 219-233.

The instability of hyperconcentrated flow observed in nature is reproducible in laboratory flumes using suspensions of bentonite. Similar instabilities are observed in a much simpler hydraulic system consisting of a container feeding a closed conduit. The behavior of two different clay suspensions, kaoline and bentonite, was investigated, and the rheological properties were measured in a rotating viscosimeter. The result of the analysis is that the instability is associated with some specific rheological properties. By a simple mathematical model, it has been explained why the bentonite suspension was unstable at small discharges and stable at sufficiently large discharges. The kaoline suspensions were always stable. The agreement between calculations and observations is encouraging.

ESCHNER, T. R., and KIRCHER, J. E. 1984. "Interpretation of Grain-Size Distributions from Measured Sediment Data, Platte River, Nebraska," Sedimentology, Vol 31, pp 569-573.

Breaks in the slope of log-probability plots of cumulative grain-size distributions of bed material are compared with frequency distributions of bed load and suspended sediment over a range of discharges at two stations on the Platte River in south-central Nebraska. The break between suspension and intermittent suspension as determined from the bed-material curve coincides with the upper limit of the grain-size overlap between bed-load particles and suspended-sediment particles, whereas the break between intermittent suspension and traction corresponds to the grain size at the lower limit of overlap of bed-load particles and suspended-sediment particles. Although grain-size distributions of bed load change little with discharge, the size of the coarsest grains in suspension increases with increasing discharge. Thus, the length of overlap of bed load and suspended-sediment distribution increases with increasing discharge. The limits of grain-size overlap of bed load and suspended-sediment distribution curves associated with near-flood discharges most closely approximate the breaks in the bed material grain-size distribution.

ETTER, R. J., HOYER, R. P., PARTHENIADES, E., and KENNEDY, J. F. 1968 (Nov). "Depositional Behavior of Kaolinite in Turbulent Flow," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 94, No. HY6, pp 1439-1452.

A rational approach to the control of shoaling in estuarial water, in which fine sediment generally plays the dominant role, requires a better understanding of the behavior of fine sediment in a flow field. Specifically, the relationships between the flow parameters, sediment properties, and rates of erosion or deposition must be investigated further before quantitative functional relationships between them can be formulated. The investigation described herein was concerned with the role of flow parameters. The unconventional experimental apparatus used consisted of a rotating annular channel and a counter-rotating annular ring within the channel.

EVANS, G. 1975. "Intertidal Flat Deposits of the Wash, Western Margin of the North Sea," Tidal Deposits, Robert N. Ginsburg, ed., Chapter 2, pp 13-20, Springer-Verlag, New York.

Both historic evidence and repeated surveying indicate coastal progradation. This progradation has produced a generally fining-upward sequence of sediments, sometimes interrupted by the deposits of the lower mud flats, which reflect the transition from the relatively high energy zones found near lower water marks to the lower energy conditions found on the salt marshes. The sediments of the zones thus form a series of flat sheets, each of which is, of course, diachronous. Only the upper part of the sequence has been proven in pits, and it is possible that there has been in some places a vertical in situ build-up of sediments rather than a horizontal progradation. This fining-upward sequence--approximately 7.0 meters thick, of laminated and interlaminated sand, silty sands to silty clays--is interrupted by deposits of meandering creeks that often show large-scale trough cross-stratified units due to sideways infilling. Available evidence suggests that the creeks are restricted to meander belts and do not rework the whole intertidal flats; however, meander belts of adjacent creeks may unite in some locations to completely replace the flat sheets of deposits of the various zones with creek deposits.

Without man's interference, the broad coastal plain of reclaimed intertidal flats would have been covered by swamp in which peat would have accumulated so that the natural top unit of the sequence would be peat or, in the geologic column, coal. The whole sequence has an abundant but poorly diversified infauna and epifauna with trace fossils produced by burrowing worms and in situ mollusks forming the dominant element; mixed with these is a derived, displaced, and in situ restricted microfauna. If the offshore channel became infilled and the intertidal flat built seaward over it, the intertidal flat sequence of sediments would be underlain by up to 10 meters of offshore channel sediment, which consists of festoon cross-bedded sands with silty clay drapes interbedded with gravels composed of mainly shells and silty-clay clasts.

EVANS, J. W. 1970 (Jun). "A Method for Measurement of the Rate of Intertidal Erosion," Bulletin of Marine Science, Vol 20, No. 2, pp 305-314.

A method is described for measuring directly the rate of erosion in the intertidal zone. Basically, this method consists of the implantation of permanent benchmarks to which can be attached, at intervals, a specially designed drawing table. This table is used to obtain, over a period of years, a series of contour drawings of the rock surface. Precautions are taken to ensure that, when subsequent contours are to be drawn in a given location, the table is set up in exactly the same position.

The apparatus can be used in any circumstance where the measurement of a gradual erosion or accretion of a hard substrate is desired.

EXTON, R. J., HOUGHTON, W. M., and ESAIAS, W. 1983. "Spectral Differences and Temporal Stability of Phycoerythrin Fluorescence in Estuarine and Coastal Waters Due to the Domination of Labile Cryptophytes and Stabile Cyanobacteria," Limnology and Oceanography, Vol 28, No. 6, pp 1225-1231.

Laser fluorosensing and epifluorescence microscopy were used jointly to identify the origin of different spectral peaks of phycoerythrin in estuarine and coastal samples. The fluorescence of the samples was also examined as a function of the time elapsed after a water circulation system was turned on. Coastal samples were dominated by cyanobacteria and exhibited a constant phycoerythrin fluorescence of the Chesapeake Bay estuarine samples first increased strongly, reached a maximum, and then decreased to below the original level; these samples were dominated by cryptophytes which epifluorescence techniques revealed were being destroyed by the circulation system. A simple mathematical model was developed to describe the effects of cell disruption, the uncoupling of energy transfer between pigments, and the subsequent breakdown of the solubilized phycoerythrin.

F

FAAS, R. W. 1970. "Consolidation Characteristics of Estuarine Sediments," Geological Society of American Abstracts, Vol 2, No. 3, p 208.

Analysis of the mass and engineering properties of selected bottom sediments from the York and James Rivers of southeastern Virginia shows that significant differences exist in these properties within the same sediment type, between both rivers. York River silty clays exhibit apparent "overconsolidation" while the same class of sediments in the James appear "normally consolidated". Significant differences in moisture contents and bulk properties also occur, with greatest water content being found in the "overconsolidated" sediments.

Clay minerals and cation exchange capacity of the sediments differ between both rivers, leading one to suspect that these are significant factors in determining the consolidation states of these saturated sediments.

FEDERAL INTER-AGENCY RIVER BASIN COMMITTEE. 1953 (Apr). "Accuracy of Sediment Size Analyses Made by the Bottom Withdrawal Tube Method," Report No. 10, Project Offices of Cooperating Agencies at St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minn.

The primary purpose of this investigation was to determine the accuracy of the bottom withdrawal tube method when applied to the size analysis of suspended sediments in the range of sand sizes. Tests were confined to sizes under 700 microns (0.7 mm) because that size limit is seldom exceeded in suspended sediments.

Glass beads were used as a sedimentation material in order to provide a more precise check on this size analysis method than would be possible with a material composed of irregular shapes. The sphericity, density, and fall velocity of the beads were established.

Report No. 7 of this series, "New Methods for Size Analysis of Suspended Sediment Samples," presented the bottom withdrawal tube method of size analysis. This method was suggested for use in the analysis of sediment samples having concentrations of from 300 to 10,000 ppm and for sediment sizes up to 1,000 microns (1.0 mm). The method was developed in the years immediately preceding 1943 but, because of the national emergency existing at that time, it was not subjected to very extensive or conclusive tests for accuracy, especially for the analysis of sediments in the sand size range. The further tests reported here were necessary to more clearly evaluate the limits of application and the accuracy of this method.

Six duplicate samples of glass beads representing thirty combinations of size range and concentration were prepared, and a pair of each were analyzed for size distribution by the bottom withdrawal tube method in each of three sedimentation laboratories. The results are compared in this report with the basic Odén curves computed from the known size distributions in the samples. The results are also presented in a form to show the consistency obtained by analyses at various concentrations and in different size ranges, and conclusions are drawn as to the accuracy and consistency of results obtained by the bottom withdrawal tube method.

FEDERAL INTER-AGENCY RIVER BASIN COMMITTEE. 1957 (Dec). "Some Fundamentals of Particle Size Analysis," Report No. 12, Project Offices of Cooperating Agencies at St. Anthony Falls Hydraulic Laboratory, Minneapolis, Minn.

Some of the basic concepts, definitions, and relations essential to particle size analysis are discussed. The relations between various measures of particle size are illustrated with data for sand sizes of sediment.

Fall velocity is emphasized both in importance and in relation to physical size. Data on the effect of concentration on fall velocity are presented, but the available information is insufficient for adequate coverage of the problem.

A method of preparing sand samples having a known fall-velocity distribution is outlined. Such samples may be used to study the effect of concentration on fall-velocity and to calibrate methods and equipment for sedimentation-size analysis.

FEKE, D. L., and SCHOWALTER, W. R. 1983. "The Effect of Brownian Diffusion on Shear-Induced Coagulation of Colloidal Dispersion," Journal of Fluid Mechanics, Vol 133, pp 17-35.

The effect of a small amount of Brownian diffusion on shear-induced coagulation of spherical particles has been calculated. This has been accomplished by considering the binary collision process between a test sphere and identical spheres interacting with the test sphere through induced-dipole attraction, electrostatic repulsion, and hydrodynamically induced forces. The effect of diffusion is found by means of an expansion in inverse Peclet number. Specific calculations were performed for uniaxial extension and for laminar shear flow. It is found that Brownian diffusion, the effect of which is nonlinearly coupled with flow type and strength, can act to increase or decrease the coagulation rate.

FEUILLET, J., and FLEISCHER, P. 1980 (Mar). "Estuarine Circulation: Controlling Factor of Clay Mineral Distribution in James River Estuary, Virginia," Journal of Sedimentary Petrology, Vol 50, No. 1, pp 267-279.

A study of clay minerals in bottom sediments of the James River estuary, Virginia, was performed to determine the predominant factors influencing their distribution. Analyses of 151 samples indicate that the factors of differential settling, flocculation, and diagenesis have minor or no effects, whereas estuarine circulation exerts the dominant influence on the clay mineral distribution.

Two characteristic clay suites are present in the James River estuary; the James River clay suite is kaolinite-illite-dioctahedral vermiculite, and the Chesapeake Bay entrance bears an illite-chlorite montmorillonite suite. Mixing between the two suites occurs as a result of the estuarine circulation dynamics, which cause upstream transport of marine sediments. The upstream limit of mixing is located in the region where the surface of no net motion intersects the river bottom. Mutual dilution of the two suites by estuarine mixing is the predominant factor governing the clay mineral distribution of all clay minerals identified.

FISACKERLY, G. M. 1970 (May). "Estuary Entrance Umpqua River, Oregon; Hydraulic Model Investigation," Technical Report H-70-6, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The Umpqua River estuary model was of the fixed-bed type, constructed to scales of 1:300 horizontally and 1:100 vertically, and reproduced the lower 28 miles of the Umpqua River and an adjoining portion of the Pacific Ocean. The model was equipped with the necessary appurtenances for accurate reproduction and measurement of tides, tidal currents, waves, salinity intrusion, freshwater inflow, shoaling distribution, and other significant prototype phenomena. The purpose of the model study was to determine the optimum plan for the reduction of shoaling and elimination of crosscurrents in the navigation channel at the entrance.

Model verification tests indicated that the model hydraulic and salinity regimens were in satisfactory agreement with those of the prototype for comparable conditions. It therefore can be assumed that the model provided quantitative answers concerning the effects of the proposed plans on the hydraulic and salinity regimens of the estuary.

The optimum plan consisted of existing conditions plus a 2600-ft extension of the training jetty to the outer end of the south jetty. The top elevation of the extension was +14 ft mllw. Results of model tests indicate that the optimum plan eliminated the crosscurrents without aggravating the wave climate or shoaling conditions.

FLEMING, G. 1970 (Nov). "Sediment Balance of Clyde Estuary," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 96, No. HY11, pp 2219-2230.

The realization of active sediment transport research should lead to the practical solution of sediment problems confronting engineers. With this as the basic principle, research was conducted into the sediment transport rates of the rivers draining the Clyde estuary in Scotland. This estuary has had a history of development and modification which has affected its sediment balance. A brief summary of the development of the estuary in relation to sediment transport is presented herein, and defined in detail are the present (size) conditions as determined by research recently completed at Strathclyde University. The methods used in this research are included and conclusions are drawn.

FREITAG, D. R. 1960 (Jun). "Soil as a Factor in Shoaling Processes, a Literature Review," Technical Bulletin No. 4, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This literature survey was made to assess, on the basis of available information, the probable influence of soil properties on the transport, deposition, and stability of shoal materials in estuaries.

Descriptions are presented of the physical and engineering characteristics of soil, particularly the clay minerals kaolinite, montmorillonite, and illite, which are carried in suspension and may be deposited in shoal areas. The various factors influencing the process of sedimentation are discussed; these include hydraulic factors, sediment type and concentration, salinity, temperature, pH, organic matter, industrial wastes, etc. Finally, available information is presented on the mode of deposition and physical characteristics of the sediment deposits.

The results of the literature survey show that the principal source of shoal materials is suspended, fine-grained soil material carried into an estuary by freshwater streams. The suspended sediment tends to flocculate in the presence of salt water, forming aggregates which settle to the bottom and form shoals. The rate of settling is influenced primarily by the salinity of the water; temperature and turbulence of the water and nature and concentration of the soil particles are of lesser importance.

The current flow pattern in an estuary controls the extent of shoaling. Sediment movements are controlled by the currents themselves, whereas the rate of sedimentation is influenced by turbulence and the extent of mixing of fresh and salt water. The fact that near the bottom of an estuary there is usually no net flow seaward indicates that sediments settling in this region are effectively retained in the estuary.

Sand deposited in shoals does not change in physical properties with time. Density is fairly high, but resistance to erosion is that of the individual particle. The properties of clays deposited in shoals can and do change with time. Initially they are light and fluffy, but they consolidate under further accumulation of material, increasing in density and strength. However, the consolidation process is slow, and in most accumulating deposits is never complete, resulting in a deposit that has only slightly increased in density and strength below the first few feet. The erosion of clays is dependent upon the balance of erosive forces and the resistance at any point; usually they are considered highly resistant to erosion.

FREY, R. W., and BASAN, P. B. 1978. "Coastal Salt Marshes," Coastal Sedimentary Environments, R. A. Davis, Jr., ed., Chapter 3, pp 101-170, Springer-Verlag, New York.

Salt marshes, which represent the final stage in the leveling of marine delta plains or the filling of depressions, embayments, and other irregularities along coasts, are to some extent a measure of coastal stability or equilibrium. The overall sedimentary sequence is therefore a potential record of coastal history; it may reveal complete successions from original estuary, delta, lagoon, or bay floors to the highest intertidal flat, including lateral variations in contemporaneous facies or subfacies. Associated mineral suites are equally important indicators of both sources and possible recycling of coastal sediments. As habitable dwelling space for numerous organisms, some of which are uniquely adapted to stressful conditions, salt marsh substrates record many details of significance in paleoecology, ichnology, and environmental reconstruction.

The recognition of ancient marsh deposits is important for the sake of documenting not only a major depositional environment but also key phases in marine transgressions or regressions. Ancient coastal systems, in addition, contain facies that provide excellent reservoirs for hydrocarbons. In that context, the recognition of marsh facies may help indicate both the kinds of reservoirs to be expected and the spatial distribution of adjacent depositional environments. The marshes associated with a particular coastal system, whether barrier islands, saline-to-brackish estuaries or deltas, embayments, or "zero-energy" coasts, therefore can be of fundamental importance in the search for new oil and gas reserves, and probably for certain coals as well.

The search for an understanding of marshes and marsh processes thus is not merely an academic exercise in science; instead, such studies have important, far-reaching implications for the quality of our own lives. This chapter, therefore, is meant not only to introduce students to an integral part of the interesting, valuable, and at times fragile coastal system, but also to encourage and stimulate research in area where most of the work remains unfinished. Indeed, some of it has hardly begun.

G

GALLENNE, B. 1974 (Jul). "Study of Fine Material In Suspension In The Estuary of The Loire and Its Dynamic Grading," Estuarine and Coastal Marine Science, Vol 2, No. 3, pp 261-272.

The tidal and seasonal movements of the turbidity maximum and the fluid mud layer of the Loire estuary were investigated and related to the concentrations of different clay minerals. The concentrations of illite and montmorillonite are shown to be inversely related, while montmorillonite reaches a maximum concentration, approximately 40 percent of clay minerals present, in the zone between the turbidity maximum and the fluid mud. Seasonal variations show that the concentration of montmorillonite moves with the turbidity maximum.

GARDNER, G. C. 1975. "Deposition of Particles From a Gas Flowing Parallel to a Surface," International Journal of Multiphase Flow, Vol 2, pp 213-218.

The practicing engineer or designer frequently requires an estimate of the rate of deposition of particles from a turbulent gas stream flowing parallel to a surface. The mechanism for deposition changes with particle size, as a glance at the mass transfer coefficients indicates, and the descriptions for each mechanism, which are widely distributed in the literature, are often couched in terms awkward for direct application. The purpose of this paper is therefore to present a means for calculating the deposition rate in an amenable form.

GIBBS, R. J. 1972 (Mar). "The Accuracy of Particle-Size Analyses Utilizing Settling Tubes," Journal of Sedimentary Petrology, Vol 42, No. 1, pp 141-145.

In order to evaluate the accuracy of various settling tubes in use, experiments were conducted using settling tubes having various diameters, settling lengths, sphere sizes, and sample sizes.

GIBBS, R. J. 1977a (Mar). "Clay Mineral Segregation into the Marine Environment," Journal of Sedimentary Petrology, Vol 47, No. 1, pp 237-243.

Based on the X-ray diffraction analyses of 150 bottom samples from the area of the Atlantic Ocean influenced by the Amazon River, trends in the clay mineral composition were observed. For the < 2 micron size fraction of samples from the mouth of the Amazon River for a distance of 1,400 kilometers along the shelf, montmorillonite shows a trend increasing from 27 to 40 percent, the kaolinite decreases from 36 to 32 percent, and the 10Å mica decreases from 28 to 18 percent. Chemical alteration of clay minerals accounts for very little of these trends. Differential flocculation is shown not to be an important mechanism probably because of natural organic and metallic coatings which give all the clay minerals similar flocculating properties. The study shows the dominant mechanism responsible for the laterally changing composition of the clay minerals to be the physical sorting of sediment by size.

GIBBS, R. J. 1976. "Distribution and Transport of Suspended Particulate Material of the Amazon River in the Ocean," Estuarine Processes, M. Wiley, ed., pp 35-47, Academic Press, New York.

The transport of suspended material of the Amazon River was determined based on data from seven cruises in the Amazon River/Atlantic Ocean area with measurements of currents, suspended material concentration, temperature, and salinity made at three anchored stations extending over complete tidal cycles. The suspended material is thrust out the river mouth onto the shelf where it encounters a two-layer flow with entrainment and mixing. It is also carried westward along shore by a strong ocean current, as well as by prevailing long-shore currents. Off the river mouth, transport is oceanward at all depths with the majority being transported in the lower half of the water column. There is a transition oceanward until the upper third of the water column on the outer shelf has negligible suspended material transport, the middle third is transported oceanward, and the bottom third of the column is transported landward. A state of equilibrium existing between the bottom transports produces a turbidity maximum out on the shelf oceanward of the river mouth and extending northwestward paralleling the coast. The sedimentation patterns are in opposition to the classic pattern with sands and silts on the shelf and winnowed mud being deposited on the coast.

GIBBS, R. J. 1977b. "Suspended Sediment Transport and the Turbidity Maximum," Estuaries, Geophysics, and the Environment, C. B. Officer, ed., pp 104-109, National Academy of Sciences, Washington, DC.

The phenomena of rivers discharging into estuaries are of interest to a wide variety of scientists and engineers for many reasons. The suspended materials that are discharged by rivers into estuaries and oceans transport many pollutants and are the natural material that fills our channels and harbors. From the biological and health viewpoint, the suspended materials are seen as the natural food of the filter-feeding organisms; therefore, pollutants transported by the suspended material that is discharged can adversely affect many varieties of seafood. This is one reason why a knowledge of the phenomena of a river discharging into the ocean or an estuary is critical. Understanding can intelligently estimate the fate of many pollutants. Possibly it can be learned how to divert or decrease the detrimental turbidity in regions of seafood harvesting. Another advantage to be gained from knowledge in this area is the ability to maintain the navigable waterways at lower cost by utilizing dredging techniques compatible with natural processes.

GIBBS, R. J., MATTHEWS, M. D., and LINK, D. A. 1971 (Mar). "The Relationship Between Sphere Size and Settling Velocity," Journal of Sedimentary Petrology, Vol 41, No. 1, pp 7-18.

The settling velocities in water of 216 glass spheres ranging in size from 50μ to 5000μ in diameter were determined. The size, density, and shape of these spheres were accurately known. All timing precisions were better than ½ percent, and the combined precision (size, shape, density, timing, etc.) of the velocity measurements was less than 2 percent at a 95 percent confidence level. Based on these data, an empirical equation was derived to give the relationship between sphere size and settling velocity. The range of usefulness of the equation includes from 0.1μ to 6 mm diameter spheres and, with correction factors, is extended to 50-mm diameter spheres. Practical tables are presented for various sphere diameters, water temperatures, sphere densities, and fluid salinities. The equation and sphere data are proposed for use as a basis of standardization of settling tube data and as a basis for determining the sedimentation diameter.

GILCHRIST, H. G. 1964 (Oct). "Studies on Erodibility of Cohesive Estuarial Materials," Report No. INT 39, Department of Scientific and Industrial Research, Hydraulic Research Station, Wallingford, England.

A preliminary investigation of the behavior of a cohesive estuary mud under fluid shear has been undertaken. Results appear to indicate that sediment age is an important factor in determining stability against fluid shear. Although the failure of a mechanically placed bed is somewhat progressive with increasing bed shear, it would appear that it is not difficult to conclude when general failure of the bed commences.

Laboratory studies indicate the mean size of the material to be .0057 mm. Approximately 42 percent of the material is of less than .002 mm in diameter. A plasticity index of 57 percent and a liquid limit of 91 percent are indicated; these values classify the material as a highly organic clay or highly elastic organic silt.

GILES, M. L., and CHATHAM, C. E., JR. 1974 (Jun). "Remedial Plans for Prevention of Harbor Shoaling, Port Orford, Oregon; Hydraulic Model Investigation," Technical Report No. H-74-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A 1:100-scale undistorted hydraulic model of Port Orford, Oregon, and sufficient offshore area to permit generation of the required test waves was used to develop and test several plans of improvement proposed to eliminate harbor shoaling without adversely affecting wave heights at the existing pier. Improvement plans consisted of (a) removal of portions of the existing breakwater, (b) realignment or lengthening of the existing breakwater, and (c) construction of new breakwater structures in the vicinity of Fort Point and Battle Rock. A 54-ft-long wave machine, electrical wave height measuring and recording apparatus, and coal and nylon tracer materials were used in the model.

Tests were conducted with prebreakwater and existing breakwater conditions, and the results were compared to determine the causes and sources of harbor shoaling. Improvement plans were then tested and compared with existing prototype conditions.

GINSBURG, R. N., and HARDIE, L. A. 1975. "Tidal and Storm Deposits, Northwestern Andros Island, Bahamas," Tidal Deposits, R. N. Ginsburg, ed., Section III, Chapter 23, pp 201-208, Springer-Verlag, New York.

The distribution of structures and organisms in the Andros area shows that in an area of low tidal range, climate, wind, and rainfall play a much larger role than in areas of larger tidal range. The remarkably sensitive zonation of sedimentary and organic structures is related to the regimen of local sea-level fluctuations, of which only a part is the semidiurnal tides. Almost all deposition is the result of storm-generated waves and flooding.

Because of the complex topography there is no unique sequence of sedimentary structures for the entire area. However, the distribution of structures has been used to guide the interpretations of ancient shoaling carbonates.

GLEN, N. C. 1979. "Tidal Measurement," Estuarine Hydrography and Sedimentation, K. R. Dyer, ed., pp 19-40, Cambridge University Press, Cambridge, England.

Tidal variations in the water level in estuaries are generally greater than those in the open sea. There can also be large variations within any one estuary due to funnelling, slowing down of the tidal wave, and frictional dissipation. The funnelling can lead to an increase of range in the outer parts of the estuary and then the frictional dissipation to a decrease near the head. The water slopes, which are important in echo sounding, are extremely variable, and without proper tidal observations, any estimate is liable to error. In general terms, the levels at high water can be expected to be much more nearly horizontal than those at low water.

Tidal measurements are required for the following purposes:

a. For the construction of navigational charts, echo-sounding surveys must be converted to a datum. Initially, observations should be carried out to establish the level of the lowest astronomical tide, at which the datum is generally placed. Once this has been done, tide measurements will need to be taken during the surveys.

b. To provide predictions for navigational purposes, continuous records are necessary. Many estuaries show large changes in water level with atmospheric pressure and wind. For vessels operating with minimal underkeel clearance actual, rather than predicted levels may be required.

c. For tidal research, a period of at least a month is required. This will give the astronomical constants for prediction and may provide empirical weather correction factors. Many tide gages are operated to give surge and flood warnings.

GOLDSMITH, V. 1971. "Coastal Dunes," Coastal Sedimentary Environments, R. A. Davis, Jr., ed., Chapter 4, pp 171-235, Springer-Verlag, New York.

The importance of eolian deposition in coastal areas is clearly demonstrated by the size and bulk of coastal sand dunes in many areas. The dune fields of Coos Bay, Oregon, the southern end of Lake Michigan, and the Cape Cod dune fields southeast of Provincetown and on Sandy Neck are just a few outstanding examples. Smaller sand dune accumulations are an integral part of almost all depositional coasts. More subtle forms of eolian deposition on beaches, marshes, and intertidal sand beaches, and in shallow bays and estuaries, may not be as noticeable but are also of importance. Eolian deposition on beaches, together with storm washover deposition in dune areas, may account in part for the lack of environmentally definitive grain-size criteria in many areas. Clearly, eolian deposits form an imposing percentage of total sediment accumulations on depositional coasts.

This chapter examines first, the external forms and internal geometry of eolian sedimentation in coastal areas; second, the physical processes and materials of sediment accumulation; and finally, the controversial role of humans in both decolonizing dunes and in promoting dune growth via artificially inseminated vegetated coastal dunes.

GOLDSMITH, V., BYRNE, R. J., SALLENGER, A. H., and DRUCKER, D. M. 1975. "The Influence of Waves on the Origin and Development of the Offset Coastal Inlets of the Southern Delmarva Peninsula, Virginia," Estuarine Research, Vol II, L. E. Cronin, ed., pp 183-200, Academic Press, New York.

Comparisons of the bathymetric surveys of 1852 and 1934 indicate that during that 82-year interval these barrier islands became substantially offset (up to 1 km) seaward on the downdrift side of the inlets. The inlets migrated southward while the ebb-tidal deltas remained stationary. The offshore bathymetry underwent concomitant changes within the same 82-year interval, most notably in the ridge-and-swale bathymetry, which deepened in the troughs and built upward on the crests. This and other detailed analyses of the bathymetry has encouraged high confidence in the older bathymetric survey.

Using standard computational wave-refraction techniques and the older bathymetry, it was determined that in 1852 the shorter-wavelength northeast waves (T = 4 to 6 sec) tended to concentrate wave energy at the south ends of these islands, whereas longer northeast waves (T = 12 sec) tended to concentrate wave energy at the north ends of the islands. Moreover, the longer waves approached the shore with their wave orthogonals closer to the perpendicular of the shoreline than did the shorter waves. Thus, the more accretional waves built up the shoreline on the downdrift sides of the inlets, while the shorter erosional waves eroded the shoreline on the updrift sides. This effect was amplified by a feedback mechanism: the more the inlet offset the greater the refraction of the longer waves, which resulted in more buildup and a decrease in littoral drift, especially to the north. This computed wave behavior is consistent with both the long-term volumetric stability and the extreme volumetric fluctuations observed annually by DeAlteris and Byrne for these offset inlets. However, since 1852 there has been a tendency for the shoreline wave-energy distribution to become more uniform along any one of these barrier islands, which suggests that when the wave-energy distribution reaches equilibrium the growth of the inlet offsets will cease, and the inlets will become more stable.

GOLE, C. V., TARAPORE, Z. S., and BRAHME, S. B. No date. "Prediction of Siltation in Harbour Basins and Channels," International Association for Hydraulic Research, pp 33-40.

No reliable method is available in the literature so far to estimate the probable siltation in harbors on completion of harbor expansion schemes. A method has been developed by the Central Water and Power Research Station, Poona, India, for the prediction of siltation in harbor basins and channels. This method is based on the analysis of the prototype and model data and the theoretical and analytical studies. A coefficient 'K' which indicates the ratio of actual siltation to the effective silt load entering the area of development is first evaluated from the known dredging and other data of existing ports and the same value is then utilized for other ports under similar situations.

GOLE, C. V., TARAPORE, Z. S., and GADRE, M. R. 1973. "Siltation in Tidal Docks Due to Density Currents," Proceedings, 15th Congress of International Association for Hydraulic Research, Vol 1, pp 335-340.

A stationary sediment wedge was reproduced in a two-dimensional flume by permitting the denser silt-laden water to intrude into silt-free water. It was found that the sediment wedge advanced along the bottom into the silt-free water up to a point which was equal to the settling length for the suspended sediment. Under these equilibrium conditions, the velocities of inflow of silt-laden water and outflow of silt-free water were measured and related to the celerity of the interfacial wave.

GRANT, H. L., STEWART, R. W., and MOILLIET, A. 1962 (Feb). "Turbulence Spectra from a Tidal Channel," Journal of Fluid Mechanics, Vol 12-Part 2, pp 241-268.

This paper describes the use of a hot film flowmeter in the sea and presents experimental measurements of the 'downstream' component of turbulent velocity in a tidal channel. The Reynolds number of the flow is about 10^8, and the scale of the turbulence is so large that a ship is carried about to a considerable extent by the energy-containing eddies. Under these conditions, a velocity measuring probe attached to a ship cannot be used for reliable measurements in the energy-containing range of the spectrum. It is possible, however, to observe the inertial and dissipation ranges. Records have been made at various stages of the tide. The one-dimensional spectra are found to be proportional to $k^{-5/3}$ for several decades in k as predicted by Kolmogoroff, and a value is given for Kolmogoroff's constant. In the dissipation range, there is close agreement with both Kovasznay's theory and Heisenberg's theory. These two theories are not very different in the low wave-number end of the range, and the observations do not extend to high enough wave-numbers to distinguish between them.

GRIEVE, D., and FLETCHER, K. 1977 (May). "Interactions Between Zinc and Suspended Sediments in the Fraser River Estuary, British-Columbia," Estuarine and Coastal Marine Science, Vol 5, No. 3, pp 415-419.

Behavior of Zn has been studied in the Fraser River estuary. Increases in dissolved and suspended Zn in the mixing zone between fresh and brackish waters demonstrate the importance of both adsorption and desorption phenomena in estuarine waters. Together with estuarine circulation these processes provide a mechanism for retention of heavy metals in coastal zone sediments and waters.

GRIFFIN, G. M., and INGRAM, R. L. 1955 (Mar-Dec). "Clay Minerals of the Neuse River Estuary," <u>Journal of Sedimentary Petrology,</u> Vol 25, No. 3, pp 194-200.

The clay fractions of 24 Neuse River estuary bottom samples were analyzed by X-ray diffraction techniques to determine the clay mineral content and to note any diagenetic changes in the clays as they were introduced into a brackish-water environment. Kaolinite and "chlorite" were present in all 24 samples and illite in 18. Kaolinite was by far the dominant clay mineral being introduced into the estuary, but it decreased considerably relative to "chlorite" and illite as increasingly saltier water was encountered downstream. Chlorite increased downstream becoming the dominant mineral at the lower end of the estuary. Illite, though very subordinate to both kaolinite and chlorite throughout the estuary, showed a definite increase in the last few downstream samples and appeared to be increasing more rapidly than chlorite.

The chlorite was thermally unstable and collapsed to a 10Å structure when heated at 400° C for one hour; however, it was like normal chlorite in retaining the 14Å basal spacing when treated with ammonium salts or glycerol.

GROSS, M. G. 1967. "Concentrations of Minor Elements in Diatomaceous Sediments of a Stagnant Fjord," Estuaries, G. H. Lauff, ed., pp 273-282, American Association for the Advancement of Science, Publication No. 83, Washington, DC.

The marine sediments of Saanich Inlet, British Columbia, were chosen for an initial survey of the effect of biological, chemical, and sedimentary processes on the concentrations of minor elements in sediments deposited in a sulfide environment. The Saanich Inlet sediments are the result of deposition in a sedimentary environment formed by an isolated part of an estuarine system, the Strait of Georgia. The isolation of the inlet permits an evaluation of the processes which affect the sediments deposited in it. Analytical techniques were chosen which would provide the best coverage of the most elements, even at the sacrifice of some precision, in order to determine the major effects of the environment.

GROSS, M. G. 1977. "Distribution of Sediment Deposits," Oceanography, A View of the Earth, pp 125-134, Prentice-Hall, Englewood Cliffs, NJ.

Various transport processes are reflected in the distribution of marine sediments. In general, river-transported sediments are distributed to continental margins. Most sediment remains on the shelf or rise except where turbidity currents are active and can carry material out into the deep ocean.

GUILCHER, A. 1967. "Origin of Sediments in Estuaries," G. H. Lauff, ed., pp 149-157, American Association for the Advancement of Science Publication No. 83, Washington, DC.

The origin of sediments in estuaries has been widely discussed in Europe and America during the past 25 years. These discussions have led to differing conclusions, which may be ascribed either to the contrasts between areas and estuaries, or to differences in methods of investigation and schools of research. Conflicting findings can exist because the same estuary has been studied by two qualified teams of geologists using different methods and different basic principles.

Since rivers carry suspended materials in their upper and middle courses, one theory supported by a number of geologists is that the sediments found in the estuaries have come from inland. Others believe that estuarine sediments come from the sea. In some areas, the conclusion is that they derive from Pleistocene deposits outcropping on the slopes or in the beds of the estuaries themselves. Another premise is that the source is to be found at the mouth of the estuary. All these opinions will be reviewed here.

GULARTE, R. C. 1978. Erosion of Cohesive Marine Sediment as a Rate Process, Ph.D. Dissertation, University of Rhode Island, Kingston, R.I.

Two series of tests were performed with a refrigerated water tunnel to determine the applicability of rate process to the erosion of cohesive material as a means of providing insight into the basic mechanisms controlling erosion.

Control variables were: average horizontal shear stress, temperature, type of clay, water content, pH, and salinity. The measured variable was the amount of material suspended as a function of time.

Results of this research show that experimental activation energies are of sufficient magnitude to suggest that erosion occurs as the result of the breaking of relatively strong solid-to-solid bonds as in soil creep. However, the experimental flow volumes were essentially five orders of magnitude larger than those obtained from soil creep studies. This suggests the possibility of the flow units being individual particles or flocs.

GULARTE, R. C., KELLY, W. E., and NACCI, V. A. 1977 (Nov). "Threshold Erosional Velocities and Rates of Erosion for Redeposited Estuarine Dredge Materials," Proceedings, Second International Symposium on Dredging Technology, Vol 1, Paper No. H3, pp 23-30.

The work reported herein is concerned with the determination of threshold erosional shear stresses and rates of erosion for ocean redeposited polluted estuarine dredge spoils. The dredged materials studied were obtained from the Taunton River (Fall River, Massachusetts) and the Thames River (New London, Connecticut).

To simulate the nearshore environment, a recirculating water tunnel was constructed, which allowed the average velocity of the eroding seawater, the average shear stress of the sediment, and the amount of material eroded to be continuously monitored during testing.

GUST, G., and WALGER, E. 1976. "The Influence of Suspended Cohesive Sediments on Boundary-Layer Structure and Erosive Activity of Turbulent Seawater Flow," Marine Geology, Vol 22, pp 189-206.

Velocity and suspension measurements in the logarithmic layer of hydraulically smooth turbulent tidal flow from the North Sea are reported. The data were not compatible with the assumption of Newtonian flow for the experimental seawater-clay suspension.

Laboratory measurements were initiated with mud and seawater from the North Sea in which the boundary-layer structure of this two-phase flow was measured down into the viscous sublayer. The dilute seawater-clay suspension was a mixture of illite, kaolinite, and chlorite minerals with concentrations less than 380 mg/ℓ and exhibited turbulent drag reduction.

By reviewing flow measurements of other authors, it is suggested that turbulent drag reduction occurs on a geophysical scale if the flows transport cohesive sediments. It is proposed that drag reduction is caused by dynamic interaction between turbulent shear strain in the flow and deformation of aggregates.

GVAZAVA, G. N., and LOMTATIDZE, V. G. 1971. "On the Problem of Sedimentation of Unbound Silts in River Mouths," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, No. 14, pp 111-116.

In this paper, the problem of unbound silts at a river flow running is considered in a reservoir with rapidly increasing depth. To derive one dimensional equation of hydrodynamics for a turbulent flow of carrying suspension stream, we use general equations of hydromechanics for two-phase turbulent stream in the form of equations of academician Kholmogorov. The mentioned equations after corresponding transformations (using the scheme of covered nappe of Professor Abramovich) are degenerated into a linear differential equation. The solution of the latter allows to determine the region of sedimentation of different silt grade as a function of the distance from the mouth range.

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HAMPTON, L. D. 1967. "Acoustic Properties of Sediments," Journal of the Acoustical Society of America, Vol 42, No. 4, pp 882-890.

This is a summary of an experimental study to measure the acoustic properties of water-saturated sediments. The sediments used were laboratory prepared to allow control of physical parameters (such as grain size, volume concentration, compressibility, etc.) and to approximate natural sediments. Acoustic velocity and attenuation in the sediments were measured over the frequency range 4 to 600 kHz. Acoustic measurements were made at high frequencies by means of two probes inserted in the sediments, and at low frequencies by means of a specially constructed rigid-wall standing-wave tube. The data presented show the frequency dependence of attenuation and velocity in the laboratory-prepared sediments and the change in this frequency dependence with changes in physical parameters of the sediments. Sediments composed of pure kaolinite, or kaolinite and sand up to 15 percent (by weight), show an $f^{1.37}$ frequency dependence of attenuation. Sediments with greater than 30 percent sand (by weight), including pure sand, exhibit an $f^{0.5}$ frequency dependence of attenuation. The measured velocity dispersion is approximately 2 percent over the frequency range 4 to 200 kHz. Velocity increases with frequency. All measurements reported are for sediments free of entrapped gas.

HARLEMAN, D. R. F., and IPPEN, A. T. 1969 (Jan). "Salinity Intrusion Effects in Estuary Shoaling," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 95, No. HY1, pp 9-27.

The purpose of this paper is to review a method of predicting the change in the longitudinal location of heavy shoaling caused by changes in the estuary regime. The method is applicable to estuaries in which the salinity distribution is of the partially or well-mixed type. It should be advantageous in the project planning stage and as a basis for decision as to whether more detailed studies, such as a hydraulic model, are advisable.

A one-dimensional method of analysis is not adequate for the consideration of sedimentation phenomena in partially or well-mixed estuaries. The existence of both longitudinal and vertical salinity gradients gives rise to marked changes in the vertical distribution of longitudinal velocity. Within the region of salinity intrusion, the variation of the longitudinal velocity with depth exhibits a net (over a tidal period) seaward flow near the surface and a net landward flow near the bottom. Since material in suspension tends to flocculate in a saline environment, the flocs settle toward the bottom and are carried in the landward direction to form shoals near the zone where the time average bottom velocity changes from the landward to the seaward direction.

The objective of this study is to obtain a quantitative correlation between salinity and velocity distributions. Experimental observations of salinity and velocity for an existing estuary condition are plotted in a dimensionless manner which define a characteristic "null point" for the estuary. The "null point" is defined as the longitudinal position at which the tidal time average velocity near the bottom changes from a landward to a seaward direction. The longitudinal shift of this "null point" or "stagnation point" can then be predicted for changes in freshwater discharge or estuary geometry. The dimensionless correlation is developed initially from data obtained in laboratory estuaries. The validity of the method is tested using data for the Delaware and Savannah estuaries.

HARRIS, J. W. 1964. "Development of Hydraulic and Shoaling Characteristics of Savannah Harbor, Georgia, by Prototype Studies and Hydraulic Model," Coastal Engineering, Proceedings, Ninth Conference on Coastal Engineering, Chapter 25, pp 378-402, Lisbon, Portugal.

Maintenance of Savannah Harbor became progressively more critical as the deepening of the channels caused heavy shoaling concentrations in a highly industrialized section of the harbor where spoil disposal areas are limited. Studies were performed to evaluate the shoaling and develop means of reducing the high cost of maintaining 31 miles of deep-water navigation channels. A hydraulic model investigation substantiated the conclusions reached through analysis of prototype data, greatly expanded the knowledge of hydraulic conditions and shoaling processes, and developed an improvement plan which involved a tide gate to induce the deposit of sediment in an off-channel sediment basin.

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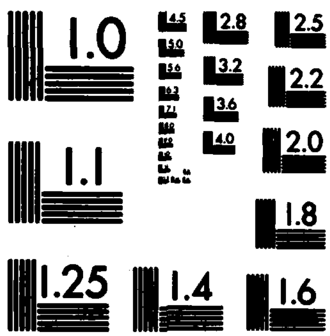

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HARRIS, J. W. 1965. "Means and Methods of Inducing Sediment Deposition and Removal," Miscellaneous Publication 970, Proceedings, Federal Inter-agency Sedimentation Conference, Symposium 3--Sedimentation in Estuaries, Harbors, and Coastal Areas, US Department of Agriculture, pp 669-674.

Maintenance of Savannah Harbor has become progressively more critical as the deepening of the channels caused heavy shoaling concentrations in a highly industrialized section of the harbor where spoil disposal areas are limited. The Savannah Harbor model study developed means of inducing sediment deposition in areas where more economical means of removal could be utilized. The hydraulic changes expected to be produced by the proposed plan of improvement and their effects of shoaling, as well as their effect on the efficiency and cost of harbor maintenance, were discussed.

HARRISON, A. J. M., and OWEN, M. W. 1971. "Siltation of Fine Sediments in Estuaries," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, pp 1-8.

The movement of silt in an estuary can be considered as a cycle of four processes--erosion, transport in suspension, deposition, and consolidation. Since each of these is a complex and ill-defined function of both the tidal flow properties and the silt characteristics, empirical expressions have to be used to describe the relationships. Laboratory and field experiments are necessary to determine the constants in these expressions.

The paper considers the case of an artificial channel across an estuary, transverse to the tidal flow, whose depth is maintained by regular dredging. A simplified theory of siltation in these channels is developed using the empirical expressions, and the results are compared with measurements of siltation in navigation channels in the River Plate. Using typical values of the various silt characteristics based on other research, the siltation rates in these channels are shown to justify the form of the theoretical predictions.

HARRISON, S. C. 1975. "Tidal-Flat Complex, Delmarva Peninsula, Virginia," Tidal Deposits, R. N. Ginsburg, ed., Section I, Chapter 4, pp 31-38, Springer-Verlag, New York.

This tide-flat complex faces a gently sloping continental shelf. It is 100 km long, 3 to 12 km wide, and 30 m thick. It has inlets spaced 9 km on average, 15 to 25 m deep, and 1 to 2 km wide. Currents are 1 to 2 m/sec maximum. Sediment is derived from erosion of the seaward edge. Sediment is coarse, but was abundant in silts and clays. There are three geomorphic areas: offshore marine, tidal-flat, and Pleistocene mainland.

HAWLEY, N. 1983 (Feb). "A Numerical Model of Cohesive Suspended Sediment Dynamics," NOAA Technical Memorandum ERL GLERL-42, Great Lakes Environmental Research Laboratory, Ann Arbor, Mich.

This report documents a one-dimensional finite-difference computer program that models cohesive suspended sediment dynamics in a shear flow. The model is based on Smulchowski's geometrical collision formulas. User-supplied empirical constants are necessary to determine the collision efficiency and aggregate shear strength. The model does not include biological or chemical processes or lateral advection. At present, the model is designed to reflect conditions in the Great Lakes, but by changing the boundary conditions it could be modified for other environments.

HAWLEY, N. 1982 (Nov). "Settling Velocity Distribution of Natural Aggregates," Journal of Geophysical Research, Vol 87, No. C12, pp 9489-9498.

An analysis of previous experimental determinations of aggregate settling rates for particles <100 μm in diameter shows that these particles fall significantly more quickly than Stokes' law predicts, with the deviations being most pronounced for smaller particles. This implies that previous sediment flux calculations which have used a form of Stokes' law to obtain aggregate velocities may have significantly underestimated the contribution from the smaller aggregates. The measured fall velocity distributions are described as the sum of normally distributed populations (four for the lacustrine data, two for the marine) whose means, standard deviations, and weights have been determined. Sample calculations of collision frequency show that because of the increased settling velocities and the use of a distribution of velocities for a given particle size, collisions due to differential settling rates are the governing nonbiological process in the formation of natural aggregates.

HAYES, M. O. 1980 (Apr). "General Morphology and Sediment Patterns in Tidal Inlets," Sedimentary Geology, Vol 26, No. 1/3, pp 139-156.

Tidal inlet sediments make up a significant portion of most barrier island complexes. Inlet-affiliated sedimentary units usually include an ebb-tidal delta (seaward shoal), a flood-tidal delta (landward shoal), and inlet-fill sequences created by inlet migration and recurved spit growth.

The morphological components of ebb-tidal deltas include a main ebb channel flanked by linear bars on either side and a terminal sand lobe at the seaward end. This channel is bordered by a platform of sand dominated by swash bars which is separated from adjacent barrier beaches by marginal flood channels. The ebb-delta sand body is coarser-grained than other sedimentary units of the inlet and contains polymodal cross-bedding with a slight ebb dominance.

Flood-tidal deltas consist of a flood ramp and bifurcating flood channels on the seaward side, which are dominated by flood currents and flood-oriented sand waves, and ebb shields, ebb spits, and spillover lobes on the landward side, which contain an abundance of ebb-oriented bedforms. A proposed stratigraphic sequence for a typical flood-tidal delta contains bidirectional, large-scale crossbedded sand at the base, predominantly large-scale (flood-oriented) crossbedded sand in the middle, and finer-grained tidal flat and marsh sediment at the top.

Inlets migrate at rates that vary from a few to several tens of meters per year, depending upon such variables as rate of longshore sediment transport and depth of the inlet. Inlet-fill sequences, which fine upward, contain coarse, bidirectional crossbedded sediments at the base, polydirectional crossbedded sands in the middle, and finer-grained aeolian sand at the top.

Both tidal-delta morphology and relative size and abundance of ebb- and flood-tidal deltas are considerably different in different oceanographic settings. Microtidal (tidal range T. R. = 0 to 2 m) areas tend to have smaller ebb-tidal deltas and larger flood-tidal deltas; whereas, mesotidal (T. R. = 2 to 4 m) areas show just the opposite trend. Large waves tend to inhibit the development of ebb-tidal deltas and accentuate the growth of flood-tidal deltas.

HAYTER, E. J. 1984. "Consideration of Cohesive Sediment Transport in Water Quality Management," Report No. UFL/COEL-84/002, pp 1-16, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, Fla.

Water quality problems related to cohesive sediments require an understanding of the movement of such sediment in suspension and associated bed scour or shoaling. A model for predicting depth-averaged sediment concentration variation and bed changes has been developed. Sediment erosion, transport, deposition, and consolidation are simulated using appropriate mathematical descriptions. Model application has been described with reference to shoaling in a coastal marina basin.

HAYTER, E. J., and MEHTA, A. J. 1982 (Dec). "Modeling of Estuarial Fine Sediment Transport for Tracking Pollutant Movement," Report No. UFL/COEL-82/009, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, Fla.

Laboratory experiments were carried out to determine: (a) the resuspension characteristics of partially consolidated, flow-deposited cohesive sediment beds under turbulent flows, (b) the effects of salinity on the rates of erosion of these beds, and (c) the effects of salinity on the rates of deposition and the settling velocity of suspended cohesive sediments under turbulent flows. The experimental results together with other available information have been used to upgrade SEDIMENT III, a two-dimensional, depth-averaged finite element cohesive sediment transport model. The purpose of the new model, SEDIMENT IIIA, is to assist in the prediction of the fate of pollutants sorbed to cohesive sediments in rivers and estuaries.

Resuspension tests conducted in a rotating annular flume and in a straight recirculating flume at the University of Florida using kaolinite and a natural mud revealed that flow-deposited beds are stratified with respect to bed shear strength and density and can consist of unconsolidated stationary suspensions, partially consolidated beds, and settled, fully consolidated beds. Both the cohesive shear strength and the bed density increase with increasing period of consolidation. When subjected to an excess bed shear stress, stationary suspensions erode almost instantly, while partially and fully consolidated beds undergo surface (aggregate by aggregate) erosion. An empirical expression for the rate of surface erosion of partially consolidated beds, that is analogous to the rate expression which results from a heuristic interpretation of the rate process theory of chemical reactions, was derived. This rate expression indicates that the rate of erosion varies exponentially with the excess bed shear stress. The rate of erosion of settled beds is linearly proportional to the excess shear stress.

A cohesive sediment bed schematization algorithm and an erosion algorithm have been developed. The erosion algorithm simulates mass erosion of stationary suspensions and the surface erosion of partially consolidated and settled beds. The bed schematization includes these three bed sections and divides each section into discretized layers.

The rates of deposition of the natural mud were found to increase with increasing salinity.

HAZEN, A. 1904 (Apr). "On Sedimentation," American Society of Civil Engineers, Vol XXX, No. 4, pp 351-376.

The writer believes that, while the internal motions keep the water mixed, and with nearly the same density of sediment from top to bottom, the tendency of the particles of sediment to settle is nevertheless an unbalanced force always acting to take the particles to the bottom. The number of particles that hit the bottom in a given time is proportional, first to the velocity at which the individual particles settle, and second to the density of sediment in the water immediately above the bottom.

The fundamental propositions are: First, that the results obtained are dependent upon the area of bottom surface exposed to receive sediment, and that they are entirely independent of the depth of basin; and second, that the best results are obtained when the basins are arranged so that the incoming water containing the maximum quantity of sediment is kept from mixing with water which is partially clarified. In other words, the best results are obtained where any given lot of water goes through the basin with the least mixing with the water which entered before it and with the water which enters after it. This is practically accomplished by dividing the basins into consecutive apartments by baffles or otherwise.

The next step is a more difficult one. It relates to bottom velocities and has to do with the question whether these velocities are such as to allow the particles to remain on the bottom when they get there, or whether they will be taken up again and be kept in motion with the body of the water.

Whatever view may be taken of the second part of the problem or whatever researches upon it may show, the arrangements of basins most favorable to taking particles to the bottom should stand.

The computations made in this paper show the reasons for several forms of construction already successfully used and suggest further possible improvements in design.

HEKEL, H., JONES, M., and SEARLE, D. E. 1976 (Jan). "Relict Sediments in Moreton Bay," Queensland Government Mining Journal, Vol 76, No. 891, pp 36-45.

Preliminary results of a soft sediment coring program, combined with continuous seismic reflection profiling in the central part of Moreton Bay are presented. Investigations indicated that wide areas are devoid of present-day sediments, and in such areas, relict sediments, which are not representative of present-day sedimentary conditions, are exposed. The development of several erosion surfaces, during Pleistocene low sea-level stands, is inferred. Continental sediments were found on some of these surfaces and their nature confirmed by sedimentological studies. Drowned intertidal terraces were observed at depths of -4, -7, and -20 m relative to Low Water Datum.

HERRMANN, F. A., JR., and TALLANT, I. C. 1972 (Sep). "Plans for Reduction of Shoaling in Brunswick Harbor and Jekyll Creek, Georgia; Hydraulic Model Investigation," Technical Report No. H-72-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A fixed-bed model of Brunswick Harbor, constructed to scales of 1:500 horizontally and 1:100 vertically, reproduced approximately 67 square miles of prototype area beginning in St. Simons Sound and extending to the upper portions of the Brunswick and Turtle Rivers and including all of East River and Academy Creek, the extensive system of saltwater creeks and marshes that affect tidal action in the area, and the Intracoastal Waterway from Brunswick River through Jekyll Creek to the U.S. Highway 84 Bridge. The model was equipped with the necessary appurtenances for the accurate reproduction of tides, tidal currents, shoaling patterns, and other significant prototype phenomena. The primary purpose of the model study was to test the effectiveness of proposed plans for the reduction of shoaling in Brunswick Harbor; however, tests of plans to reduce shoaling in Jekyll Creek were later added to the overall testing program.

Model verification tests indicated that the hydraulic and shoaling regimens were in satisfactory agreement with those of the prototype for comparable conditions. It therefore can be assumed that the model provided quantitative answers concerning the effects of the proposed improvement plans on the hydraulic regimen of the prototype area reproduced and reliable qualitative answers as to the effects of proposed improvements on shoaling rates and patterns in navigation channels.

It was determined that closure of the East River channel was the only scheme tested which could effect significant reduction of shoaling. Schemes to increase current velocities or turbulence were unsuccessful in reducing channel shoaling in the critical reach of East River. It was concluded that deepening the navigation channel from 30 ft to 36 ft will reduce shoaling in East River and increase shoaling in Turtle and Brunswick Rivers, even if no additional improvement works are constructed.

A plan consisting of 10,150 ft of impermeable training walls was developed for reducing shoaling in Jekyll Creek. This plan reduced overall shoaling in the channel and shifted substantial amounts of shoal material from areas of high-cost maintenance to areas of low-cost maintenance.

HINE, A. C. 1975. "Bedform Distribution and Migration Patterns on Tidal Deltas in the Chatham Harbor Estuary, Cape Cod, Massachusetts," Estuarine Research, L. E. Cronin, ed., Vol II, pp 235-252, Academic Press, New York.

Well-developed, multi-component flood- and ebb-tidal deltas exist in the lower portion of the Chatham Harbor estuary, Cape Cod, Massachusetts. Each tidal delta contains several sand bodies, a dominant bedform type, and a preferred bedform orientation, which indicates a distinct sediment transport pattern. The hydrography and overall geometry of the estuary are the critical factors in controlling these features on the tidal deltas. The estuary has two inlets, each facing a separate large body of water whose tidal ranges are significantly different. The tidal-range difference develops a steep hydraulic slope that occurs during flood and results in pronounced time asymmetry and tidal-current segregation.

The ebb-tidal delta conforms to the model proposed by Hayes. Tidal-current segregation has developed a deep, main ebb channel, which is flanked by two shallow marginal flood channels. These three channels are floored with unidirectionally oriented sand waves. Net sand transport by tidal currents occurs in the proximal portion of the ebb-tidal delta, while net transport by wave-generated currents occurs in the distal portion.

Nearly complete flood-tidal current dominance exists on the flood-tidal delta. The margins of this multi-lobate sand body have migrated approximately 900 m during a 10-year period, indicating rapid sand transport. Three bedform orientations develop during flood because of two changes in the direction of flow. The resulting dominant bedform feature is an intersecting pattern of two sand-wave orientations.

HIRST, T. J., PERLOW, M., JR., RICHARDS, A. F., BURTON, B. S., and van SCIVER, W. J. 1975. "Improved In Situ Gamma-Ray Transmission Densitometer for Marine Sediments," Ocean Engineering, Vol 3, No. 1, pp 17-27.

The first-generation University of Illinois gamma-ray transmission densitometer, designed for the in situ measurement of sediment bulk density, was modified by incorporating in the detector probe (a) an Americium-241 alpha particle pulser and an anti-walk gain stabilization control to maintain better temperature stability and (b) a small power supply and a preamplifier to eliminate the need for a high-voltage coaxial cable between the detector and external signal conditioning electronics package. This second-generation Lehigh University system has been successfully deployed since 1971 in routine use from ships and submersibles in the Atlantic and Pacific Oceans and Gulf of Mexico. Results are presented of system operations to (a) measure bulk density over the range of 1.2 to 1.8 g/cu cm in the Hudson Canyon, (b) penetrate 1.9 m into the seafloor in the San Diego trough, and (c) be lowered to a water depth of 3.6 km in the Gulf of Mexico.

HIRST, T. J., and RICHARDS, A. F. 1976. "Excess Pore Pressure in Mississippi Delta Front Sediments: Initial Report," Marine Geotechnology, Vol 1, No. 4, pp 337-344.

In September 1975, a differential piezometer probe was successfully implanted in the soft seafloor sediments of Block 28, South Pass, Mississippi Delta. The probe sensor is located approximately 6.4 m below the mudline in a water depth of 19 m, and has essentially continuously monitored excess pore pressure (the difference between sediment pore pressure and hydrostatic pressure at that depth) since installation. Excess pore pressure will be monitored until March 1976, when the probe will be recovered.

Immediately after deployment, an excess pore pressure of 54 kPa was recorded. An ambient excess pore pressure of approximately 32 kPa remained after dissipation of that developed during probe installation. Because of the possible presence of gas in the sediments in this area, it is not known with certainty whether the measured excess pressure is pore water pressure, pore gas pressure, or some combination of the two. An excess pore pressure of about 32 ±4 kPa was monitored during Hurricane Eloise and subsequent storms. The exact magnitude and time distribution of this pressure fluctuations is presently being evaluated.

HO, C. L., and KARIM, H. 1978 (Jun). "Impact of Adsorbed Petroleum Hydrocarbons on Marine Organisms," Marine Pollution Bulletin, Vol 9, No. 6, pp 156-162.

Adsorptions of south Louisiana crude oil from seawater by clays, nonclay minerals, and sediments were conducted in the laboratory. Effects of sediment-adsorbed and water-dispersed crude oil on adult oysters were investigated in aquaria. Hydrocarbons in oyster tissues and surrounding water were identified by gas chromatography. Field specimens from an area of a new oil spill and an area five months after an oil spill were also analyzed. Evidence of secondary chemical effect of aged oil in sediments on oyster mortality is presented. Oil coated asbestos surfaces severely reduced recruitment of sedentary larval organisms.

HOAG, R. W., II. 1970 (Sep). Estimation of the Original Shear Strength of Deep Sea Sediments from Engineering Index Properties, M.S. Thesis, Naval Postgraduate School, Monterey, Calif.

Multiple linear regression techniques were employed in a statistical analysis of data from 114 deep sea cores in order to derive an equation for predicting shear strength from sediment engineering index properties. Water content, depth of burial, liquid limit, and plastic limit proved to be the only factors significantly influencing the strength in these cores. The multiple and individual correlation coefficients between these four parameters and the logarithm of shear strength proved to be higher than the coefficients computed in a linear strength relation. Additionally, other regression analyses were conducted to determine a water content prediction equation and to investigate correlations among other sediment properties. Water content is shown to be highly correlated with liquid limit. Ancillary to the above analysis, tests were conducted to determine the degree of reproducibility of original liquid limit values from dried sediment material.

HOFFMAN, J. F. 1976 (Jun). "Decrease in Harbor Maintenance Dredging Through the Use of Pile Dikes and Related Structures Together with an Analysis of Estuarine Sedimentation Problems," Report No. USNA-EPRD-29, US Naval Academy, Annapolis, MD.

Most harbors in the continental United States of interest to the US Navy are located within estuaries. Because of the presence of fresh water as well as salt water, special sedimentation problems are created. Eight sources of sediments in an estuary are discussed.

This report discusses a system to remove sediments by means other than dredging. The first part of the system is to entrap estuarine sediment by means of pile dikes to prevent it from entering dredged shipping channels. The second part is to remove periodically the accumulated sedimentary material by a back-flushing and slurry pumping system. Back-flushing sediments is common practice in water supply filter beds. Slurry pumping systems are presently in use to transport solids over long distances. The slurry may be pumped to barges, used as landfill, or pumped to offshore spoil disposal areas such as submarine canyons.

HOFFMAN, J. F. 1978 (Nov). "European Dredging--A Review of the State of the Art," ONR London Report R-12-78, Office of Naval Research, London, England.

The state-of-the-art of dredging in Europe is described. The details are on a three-month on-site investigation in the countries of Belgium, England, France, Germany, Holland, and Scotland. Information was obtained during conferences involving more than 40 persons. Visited were two dredging firms, one manufacturer of dredging equipment, three universities, six laboratories concerned with the hydraulics and/or sedimentation in harbors, eight port authorities, and three miscellaneous Federal agencies. New dredging technology-modifications to old dredging technology as well as dredging practices in selected European ports are discussed. The facilities and capabilities of the hydraulic laboratories visited are described.

HOFFMAN, J. F. 1981. "Sediment Problems and Their Control in U.S. Navy Pier Slips in Selected Harbors of the United States," Estuarine Comparisons, V. Kennedy, ed., pp 623-633, Academic Press, New York.

Discussed in this paper are the sedimentation problems occurring in US Navy pier slips in the harbors of Hampton Roads, Virginia; Charleston, South Carolina; Mayport, Florida; San Diego, California; and Alameda, California. These problems are related to the berthing of deep-draft vessels such as aircraft carriers where depths of water of 45 ft (13.7 m) are required. In addition to problems involving grounding and clogging of cooling water systems, both of which render a vessel inoperative, the problem of the increasing cost of dredging maintenance is encountered. Various means of sediment control in pier slips are discussed. These include the use of a single row of water jets, water jet arrays, silt curtains, agitation dredging, sand crater-eductor method, and riverflow bypassing.

HOFFMAN, R. L. 1972. "Discontinuous and Dilatant Viscosity Behavior in Concentrated Suspensions, Observation of a Flow Instability," Transactions of the Society of Rheology, Vol 16, No. 1, pp 155-173.

The rheological dilatancy of concentrated suspensions has been studied to determine the cause of this phenomenon. If monodisperse suspensions of polymeric resins are examined, dilatant viscosity behavior is transformed into a discontinuous viscosity behavior when the volume fraction of solids is raised above 0.50. Experimental evidence is presented which supports the hypothesis that the discontinuity is caused by a flow instability in which surfaces of spheres, packed in a two-dimensional hexagonal packing at low shear rates, break up into less ordered arrays of spheres. Although various techniques have been used, white light diffraction from a suspension under shear provides the most dramatic evidence of the ordered packing of the spheres and the order-disorder transition at the instability point.

HOFFMAN, R. L. 1974 (Mar). "Discontinuous and Dilatant Viscosity Behavior in Concentrated Suspensions, Theory and Experimental Tests," Journal of Colloid and Interface Science, Vol 46, No. 3, pp 491-506.

An analysis of forces which are expected to arise in colloidal systems under shear has been used to model the flow instability which leads to discontinuous and dilatant viscosity behavior in concentrated suspensions of polymeric resins. Observation of this phenomenon was reported in the first paper of this series. The analysis is carried out on the presumption that the dominant forces leading to the flow instability are van der Waals-London attraction, electric double layer repulsion and the shear stress acting on groups of particles. Conditions for the onset of the instability are cast in terms of a torque balance and an energy balance, and a set of dimensionless numbers are obtained to characterize the phenomenon. Experimental data obtained from tests on a number of concentrated suspensions are given in support of the theory.

HOLMES, C. W. 1977 (Mar-Apr). "Effects of Dredged Channels on Trace-Metal Migration in an Estuary," Journal of Research of the US Geological Survey, Vol 5, No. 2, pp 243-251.

Determination of trace-metal levels in the sediments of the Matagorda Bay system revealed anomalously high mercury values. The distribution of the mercury-rich sediment deposits is the result of the sedimentological regime of the bay system produced by the tidal currents in the dredged channel. According to this model, the oxygenated open gulf water pushed into the bay by tidal currents activates the mercury and reintroduces it into the sediment regime of the bay in an area where the turbidity maximum is most prevalent. Within this region, the absorption sites are at a maximum, tying up the mercury. The mercury-enriched suspended material is then transported and deposited according to the hydraulic regime within the bay system.

HOUSER, M. E., and FAUTH, M. I. 1972 (Jun). "Potomac River Sediment Study," Indian Head Technical Report 355, Naval Ordnance Station, Indian Head, MD.

Analyses of Potomac River sediments for approximately 20 metals have been made using atomic absorption spectrometry. Sample preparation involved extraction with water and nitric acid. The river area surveyed extended from Key Bridge to Piney Point, a distance of 96 river miles.

Data are presented for the following metals: aluminum, barium, cadmium, calcium, chromium, cobalt, copper, iron, lead, lithium, magnesium, manganese, nickel, potassium, silver, strontium, vanadium, and zinc. A few analyses were also made for mercury.

Lead content was highest at the Woodrow Wilson and Route 301 Bridges. Copper, chromium, and nickel concentrations at Woodrow Wilson Bridge and Piscataway Creek appear to be associated with major waste treatment plants whose outfalls are in the vicinity. High concentrations of manganese were found in an undeveloped section of the river.

HUANG, S., HAN, N., and ZHANG, X. 1980 (Mar). "Analysis of Siltation at Mouth Bar of the Yangtze River Estuary," The Problems of River Sedimentation and the Present Status of Its Research in China, International Symposium on River Sedimentation, pp 9-10, Beijing, China.

The Yangtze River is the largest river in China, with a total length of 6300 km. The long-term mean river discharge is 29,200 m^3/sec, and the total silt discharge approximates 500 million tons/year. At the gaging station of Zhongjun, the maximum tidal range is 4.62 m. Through the interaction of the two strong forces of river flow and tidal currents, the Yangtze River estuary is divided by islands and sandbanks in a regular way. It is divided into the south and north branches by the Chongming Island at a site downstream from Xuliuging. The south branch is likewise subdivided into two waterways, the south waterway and north waterway, by the Changxing and Hengsha Islands downstream from Wusong. Furthermore, the south waterway is again divided into the south channel and north channel by the Jiuduan sandbanks. Due to the progressive deterioration, the north branch is now obsolete for navigation. As to the north waterway and the north and south channels, there are bars at their mouths limiting the navigation depth to about 6.0 m only. An analysis of the siltation process of the mouth bar is presented in this article, and the knowledge thus provided may be beneficial for regulation of the navigation channel.

HUGGETT, R. J., NICHOLS, M., and BENDER, M. 1979 (Apr). "Kepone Contamination of the James River," American Chemical Society Division of Environmental Chemistry, Vol 19, No. 1, pp 341-342.

This paper aims first to determine the extent of Kepone contamination in the James estuary and secondly to trace the transfer routes as Kepone is cycled through the estuarine environment. The patterns of concentration and routes of transfer indicate what happens when a stable organic contaminant is released into an estuarine environment. They are also of use for predicting potential hazards of similar contaminants released into other estuaries so that preventative measures can be taken to protect sensitive areas.

HUNT, J. R. 1980. "Prediction of Oceanic Particle Size Distributions from Coagulation and Sedimentation Mechanisms," Particulates in Water, Advances in Chemistry Series No. 189, M. C. Kavanaugh and J. O. Leckie, eds., Chapter 11, pp 243-257, American Chemical Society, Washington, DC.

An explanation is offered for observed oceanic particle size distributions considering only particle removal by coagulation and sedimentation. The analysis includes three coagulation mechanisms: Brownian, shear, and differential-sedimentation, for a continuous distribution of particle size. The size distribution is assumed to be in steady state with a constant flux of particle volume through the distribution. Predicted size distributions are power-law functions of the particle diameter with exponents -2.5 for Brownian coagulation, -4.0 for shear coagulation, -4.5 for differential-sedimentation coagulation, and -4.75 for gravitational settling. Observed size distributions for oceanic waters and digested sewage sludges are compared with the predictions. One consequence of the theory is the prediction of increased particle concentration at oceanic thermoclines in response to a decrease in fluid turbulence.

HUNT, J. R. 1982. "Self-Similar Particle-Size Distributions During Coagulation: Theory and Experimental Verification," Journal of Fluid Mechanics, Vol 122, pp 169-185.

A quantitative theory for particle coagulation in continuous particle size distributions is presented and experimentally verified. The analysis, following Friedlander, assumes a local equilibrium in the size distribution maintained by a particle flux through the size distribution. Only particle collisions caused by Brownian motion, fluid shear, and differences in settling velocities are considered. For intervals of particle size where only one coagulation mechanism is dominant, dimensional analysis predicts self-similar size distributions that contain only one dimensionless constant for each mechanism. Experiments were designed to test these predictions with clay particles in artificial seawater sheared in the gap between concentric rotating cylinders. Particle-size distributions measured over time were self-similar in shape and agreed with the Brownian- and shear-coagulation prediction in terms of shape and dependence on fluid shear rate and particle volume flux through the size distribution.

HUNT, J. R., and PANDYA, J. D. 1984 (Feb). "Sewage Sludge Coagulation and Settling in Seawater," Environmental Science and Technology, Vol 18, No. 2, pp 119-121.

Sewage sludge removal from seawater is shown to be a continuous process of aggregate production by coagulation followed by settling of the largest aggregates. Anaerobically digested sewage sludge coagulation experiments in artificial seawater were conducted at fluid shear rates of 0, 0.25, 0.5, 1, 2, 4, and 8 s^{-1} with a rotating cylinder apparatus. The sludge removal rate was second order in sludge concentration and dependent on the fluid shear rate. The settling velocity of aggregates produced at a given shear rate was found to be constant.

HUNT, S. D. 1981. "A Comparative Review of Laboratory Data on Erosion of Cohesive Sediment Beds," UFL/COEL/MP-81/7, M.E. Project Report, University of Florida, Gainesville, Fla.

Experimental conditions and results from nine investigations on the erosion of cohesive sediment beds have been reviewed on a comparative basis. Test conditions have been compiled in tabular form under four headings: soil properties, pore and eroding fluid properties, bed properties, and apparatus and sampling techniques. An empirical relationship between the rate of erosion, ε, and the applied shear stress, τ, is proposed and examined relative to a total of twenty-four tests from the nine investigations. The $\varepsilon - \tau$ relationship consists of two linear segments of different slopes intersecting at a point (τ_{CH}, ε_{CH}), where ε_{CH} is defined as a characteristic erosion rate and τ_{CH} is the corresponding characteristic shear stress. Ten test results from six investigations are found to conform to this (Type I) relationship. A special case (Type II) is one involving a single linear segment which intersects the $\varepsilon = \Theta$ axis at $\tau = \tau_{cr}$, the critical shear stress. Fourteen test results from three investigations show a degree of conformity to this relationship which has been previously reported in the literature. Both relationships can be conveniently expressed in dimensionless form.

An attempt has been made to examine, briefly, the influence of such factors as clay amount, salinity, Sodium Adsorption Ratio, pore and eroding fluid compositions, fluid temperature, pH, and bed water content on soil erodibility in terms of the effect of these factors on the coefficients of the proposed relationship. It is noted that the relationship is helpful in identifying the effects of the various factors on soil erosion potential. The possibility of the existence of a relationship between the rate of change of the erosion rate and the critical shear stress is demonstrated. The scope of this work has been limited by the large amounts of undocumented physico-chemical factors in some of the investigations. Documentation of these factors is essential for test reproducibility.

HUNTER, K. A., and LISS, P. S. 1982. "Organic Matter and the Surface Charge of Suspended Particles in Estuarine Waters," Limnology and Oceanography, Vol 27, No. 2, pp 322-335.

The surface electrical charge on suspended particles in four estuaries of the United Kingdom has been measured as a function of salinity by the technique of particle microelectrophoresis. Two characteristic types of behavior were found. In rivers low in dissolved cations, especially Ca^{2+}, the electrophoretic mobility u_g was negative in sign at all salinities, increasing slightly in magnitude from the seawater end member to lower salinities of 5 to 10 percent, with a more pronounced increase toward the river water end member. In rivers draining calcareous terrain and having relatively high concentrations of Ca^{2+}, u_g showed a similar dependence on salinity above 5 to 10 percent but no marked increase in magnitude at lower salinities. Ionic composition of the water appears to be the major factor controlling changes in u_g with salinity. Positively charged particles were entirely absent. The charge distribution of all samples was highly uniform, in spite of the mixed nature of the suspended matter, indicating a dominant control of surface properties by adsorbed organic matter, metallic oxides, or both. This implies that differential flocculation of different suspended minerals is largely suppressed in the estuarine zone. Measurements of dissolved organic carbon and surface-active substances (by suppression of polarographic maximum) in the same estuaries indicate a sufficient supply of organic matter for the adsorption process. No evidence for nonconservative removal of DOC or surface-active substances was found. Sewage inputs into some of the estuaries are clearly seen by the measurements of surface-active substances. Significant quantities of surface-active materials are injected into the Alde estuary through tidal flushing of a salt marsh area.

HYDRAULICS RESEARCH STATION. 1970 (Jan). "The Effect of a Half-Tide Barrier at Either Woolwich or Blackwall on Siltation in the Estuary," Report No. EX 479, Thames Estuary Flood Prevention Investigation, Wallingford, England.

A tidal barrier has been proposed for the Thames estuary to protect Central London from flooding by North Sea storm surges. A mathematical model has been developed to assist in predicting the overall effects of such a barrier on siltation in the estuary. The model simulates the movement of water and silt in an idealized version of sixty miles of the estuary; the marked difference between the behavior of the water and suspended silt near the bed and at higher levels in the flow necessitated a two-layer model. The thin lower layer represented a boundary zone between the bed and the upper layer, in which the bulk of the flow took place. Empirical expressions based on laboratory experiments were used to describe the various processes of silt movement--erosion, transport in suspension, and deposition--which are complex and ill-defined functions of both tidal flow and silt properties.

Extensive survey data were available to establish the validity of the model, and proving was carried out for spring and neap tides at a steady freshwater discharge of twice the long-term average flow.

The model showed that a half-tide barrier at either Woolwich or Blackwall, closing at mid-ebb and opening at mid-flood tide, greatly reduced the suspended concentrations in the estuary, and tended to move the region where the silt accumulates, known as the Mud Reaches, seawards. Blackwall appeared to be a greater site than Woolwich, since the changes to the existing system were much less and relatively little dredging would be required to maintain existing depths.

HYDRAULICS RESEARCH STATION. 1969 (Feb). "River Parana, Field and Model Investigations of a New Channel Connecting Buenos Aires with the Delta of the River Parana," Report No. EX 420, Hydraulics Research Station, Wallingford, England.

The object of the field investigation was to provide sufficient information to enable a model of the River Plate and the delta of the River Parana to be operated satisfactorily and to provide an insight into the sedimentary processes in the estuary. This involved not only topographical surveys and current meter traverses of the River Plate and the major rivers, but also the collection of a large amount of data about winds, waves, tides, and river flows. Material being transported either in suspension or as bed load was sampled, as well as the material composing the bed of the rivers. In order to obtain more precise information about the pattern of sediment movement, radioactive material was deposited onto the bed of the River Plate, and its subsequent movement was tracked at a number of verticals across the section. At some of the verticals, attempts were also made to obtain samples of bed load. For each vertical in the River Plate, velocities were measured continuously at the surface, middepth, and the bottom, for periods of 20 to 30 hours. Salinity tests were made during the initial stages of the survey, but these were discontinued when no salinity was evident. This confirms the evidence of the South America Pilot which states that the seaward limit of fresh water extends to a line joining the River Santa Lucia and Punta Piedras.

HYDRAULICS RESEARCH STATION. No date. "Sediment Flux Meter," Wallingford, England.

Before valid predictions can be made of the effects that proposed engineering works are likely to have on the accretion-erosion processes in an estuary or a river channel, it is important to be able to measure existing sediment transport rates. And it is particularly important to be able to measure these rates close to the bed where sediment movement is greatest.

Equipment capable of doing this has been developed at the Hydraulics Research Station. The equipment is unique in that it can be used in water depths down to 30 m and will measure flow velocities and sand concentrations along any vertical profile starting as close as 0.05 m above the bed. The equipment consists of a rig with a support frame on which is mounted a measuring head incorporating two Braystoke current meters and a suspended solids sampling nozzle. The nozzle is connected to the suction side of a Jabsco or Mono pump. A fin on the measuring head ensures good orientation of the meters and inlet nozzle with the flow. The rig weighs about 200 kg and is lowered to rest on the bed in tethered mode from an attendant vessel. An independent streamlined unit attached to a suspension wire suffices to measure over the profile from the water surface to 0.75 m above the bed. Velocity and concentration gradients are less steep than in the near-bed layer and close elevation control is no longer critical in this region.

The measuring head of the bed unit is attached to a tensioned, endless wire drive that allows 0.65 m vertical travel. The drive for the wire is provided by a small geared motor mounted within the bed unit and remotely operated by switching from the attendant vessel. For setting up, the head is driven downwards until a plate makes contact with the bed and operates a switch to interrupt the power supply. This elevation is taken as the bed datum, and the measuring head is raised to the desired elevation, as indicated by a counter displayed on the vessel of the number of drive-shaft revolutions. In addition, two potentiometer tiltmeters mounted on the bed unit provide a measure of its roll-and-pitch angles.

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INMAN, D. L. 1963. "Sediments: Physical Properties and Mechanics of Sedimentation," Submarine Geology, 2nd Edition, C. Cronies, ed., pp 101-151, Harper and Row, New York.

Certain physical properties of sediments appear to be fundamental to the marine geologist in his study of the classification of sedimentary deposits, as well as to the student of sedimentary mechanics in his groping to understand the natural dynamics by which the sediment was transported and ultimately deposited. Density, size, and size distribution are controlling parameters in almost all the physical properties of sediments. Settling velocity, while fundamental to sedimentation and suspension, is also an important measure in determining the size of fine sediments; in which case the "equivalent size" is that of a quartz sphere having the same settling velocity as that of the less spherical natural grain. Packing and permeability become important considerations in transport by waves and currents, and the slopes of beach faces are, to a certain extent, controlled by the permeability of the beach sand. Permeability in turn is determined by the packing, size, and size distribution of the sediment grains.

Fluids and fluid properties are discussed separately from those of a mixture of granular and fluid material because the mixture has properties differing quite widely from those of the fluid alone. Fluid stresses alone are of importance in settling velocity and the initiation of grain movement. However, when the grains constitute about 9 percent or more of the grain-fluid mixture, the tangential grain-to-grain stresses dominate, and the mixture acquires a normal dispersive stress that is not possessed by the fluid alone. Considerations of these normal grain stresses and their relation to the horizontal or tangential shear have opened new horizons in the field of sediment transport. This concept has led to a rational approach to the quantitative prediction of sediment transport by waves and currents and to the formulation of general relations which may govern the flow and dimensions of phenomena such as turbidity currents.

IPPEN, A. T. 1966. "Sedimentation in Estuaries," Estuary and Coastline Hydrodynamics, A. T. Ippen, ed., pp 648-671, Chapter 15, McGraw-Hill, New York.

Field and model observations have consistently supported the analytical and experimental conclusions presented in Chapters 11, 12, and 13 on salinity intrusion and associated diffusion phenomena. Invariably major shoaling in the main channels could be connected to these estuary characteristics, and hence rational extrapolations have been possible for the prediction of shoaling effects in the planning of new engineering measures.

ITAKURA, T., and KISHI, T. 1980 (Aug). "Open Channel Flow with Suspended Sediments," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 106, No. HY8, pp 1325-1343.

In most previous studies, the velocity distributions were examined so as to fit a straight line for points plotted on a semilogarithmic paper. Thus average slopes of the lines were used to evaluate over-all values of κ. Some of the velocity distribution equations were shown by the forms of the velocity defect law. It is therefore necessary to give a value of maximum velocity, u_{max}, to calculate the exact velocity distribution and a hydraulic resistance law of the flow.

In the present study, a new attempt to describe a velocity distribution of suspended, sediment-laden flow was proposed by using a theory based on the Monin-Obukhov length. It will be shown that the experimental results for open channel flows with suspended sediments are better accounted for by this theory.

A theoretical description of velocity distribution is presented and then a hydraulic resistance law for sediment-laden flow will be established. Sections deal with the distribution of sediment concentration and the transport rate of suspended materials and include a reasonable definition of the reference concentration. Finally, some characteristics of turbulence for the flow with suspended sediments are described.

IYENGAR, S. S., DONALD, O., and De La CRUZ, A. 1975. "Computer Simulation of the Seasonal Flux of Organic Material from the St. Louis Bay Riverine and Estuarine Systems to the Mississippi Sound and North Central Gulf of Mexico," Proceedings, 8th Annual Simulation Symposium, pp 31-43, Tampa, Fla.

The richest fishing and shell fishing grounds in the world are located in coastal bays where marshes and similar tidal communities abound. For example, the Chesapeake Bay area, Georgia Golden Isles area, and the Louisiana Deltaic Estuaries, to name a few. This paper describes a development of a mathematical model to predict the state of the system with respect to organic matter transport in the river. Emphasis has been placed on maintaining flexibility and generality in the model. The program has been structured in a completely modular form so that modifications can be efficient. Predictions from this model when compared to the experimental values are fairly accurate.

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JACOBS, M. L. 1972 (Feb). "Salinity and Sedimentation Study--Cooper River Rediversion, Charleston, South Carolina," Journal of the American Water Resources Association, Vol 8, No. 1, Paper No. 72010, pp 87-92.

The study was prepared in 1966 for the Bureau of Sport Fisheries and Wildlife, Department of the Interior, for presentation to the United States Army Corps of Engineers which had under study several routes for rediversion of the discharge from the Santee-Cooper Hydroelectric Plant, Steam Plant, and Lock. Each rediversion was designed to bypass the Charleston Harbor, and this study and report were concerned with one of those routes--Rediversion Route "B." The channel was to be designed for a maximum freshwater flow of 27,500 cfs and a mean flow of 15,500 cfs. The objectives of the study and report were to make an estimate of: (a) the geographical extent of salt marsh waters of which the salinity will be measurably reduced, and (b) the probable accumulation of freshwater-borne sediments in those same waters.

JEFFREY, D. J., and ACRIVOS, A. 1976 (May). "The Rheological Properties of Suspensions of Rigid Particles," American Institute of Chemical Engineers Journal, Vol 22, No. 3, pp 417-432.

A well-known and longstanding problem in fluid mechanics has been the calculation of the effective viscosity of a suspension. In recent years it has become clear that many of the complex phenomena associated with a flowing suspension cannot be explained by using a classical Newtonian description of a fluid with an effective viscosity. Thus, suspensions have to be treated as non-Newtonian fluids whose rheological (flow) properties are influenced by a large number of variables. This review presents some of the reasons why such non-Newtonian behavior occurs and describes the variables that must be included in any proposed theory for such behavior. The discussion is restricted to suspensions of rigid, neutrally buoyant particles in Newtonian fluids and thereby excludes emulsions, reinforced plastics, etc., but otherwise no restrictions are placed on the scope of the review.

JENSEN, J. K., and SORENSEN, T. 1972 (Jul). "Measurement of Sediment Suspension in Combinations of Waves and Currents," Proceedings, Thirteenth Coastal Engineering Conference, American Society of Civil Engineers, Vol II, Chapter 58, pp 1097-1104.

The paper describes a procedure for obtaining field data on the mean concentration of sediments in combination of waves and currents outside the breaker zone, as well as some results of such measurements. It is assumed that the current turbulence alone is responsible for the maintenance of the concentration profile above a thin layer close to the bottom, in which pickup of sediments due to wave agitation takes place. This assumption gives a good agreement between field data and calculated concentration profiles.

JOGLEKAR, D. V., GOLE, C. V., and MULEKAR, S. N. 1957. "Studies in Siltation of Cochin Port," Section II, Communication 3, pp 109-118, XIXth International Congress, London, England.

The Port of Cochin is situated on the southwest coast of India about 200 miles north of the Cape Camorin, southernmost tip of India. The port was opened for traffic in 1930 by dredging a channel 450 ft wide and 16,000 ft long to a depth 37 ft below low water ordinary spring tide (LWOST) through a crescent-shaped bar only 10 ft below LWOST. The bar was about 4,000 ft west of the gut (opening to the sea). The inner harbor consists of two channels, Mattancherry and Ernakulam; these channels along with the mooring areas were initially dredged. Most of the quays are located on the Mattancherry channel, while naval ships and oil tankers are berthed in the Ernakulam channel.

The approach channel in the sea has to be dredged every year to maintain the required depths. Considerable silting takes place also in the Mattancherry channel. To investigate measures for reducing the silting, a hydraulic model to a horizontal scale of 1:1,000 and a vertical scale of 1:20 was constructed. Remedial measures tested in the model have been discussed in this paper.

JOHNS, W. D., and GRIM, R. E. 1958 (Mar-Dec). "Clay Mineral Composition of Recent Sediments from the Mississippi River Delta," Journal of Sedimentary Petrology, Vol 28, No. 2, pp 186-199.

The clay mineral composition of Recent sediments from the modern Mississippi River delta and offshore regions in the vicinity of the delta is reported. Montmorillonite is the dominant clay mineral being deposited in the delta region. A small amount of this component changes to illite and chlorite. It is suggested that this material represents degraded micaceous material undergoing regradation, and thus represents the approximate contribution of the Ohio River drainage system to clay mineral assemblage. The bulk of the montmorillonite, presumably bentonitic in character, undergoes no apparent diagenesis. It is suggested that this material represents the approximate contribution of the drainage basin of the Missouri River system.

JOHNSON, H. P., and MOLDENHAUER, W. C. 1970. "Pollution by Sediment: Sources and the Detachment and Transport Processes," Agricultural Practices and Water Quality, T. L. Willrich and G. E. Smith, eds., pp 3-20, The Iowa State University Press, Ames, Iowa.

While erosion has been active over geologic time, man has often altered the process to the detriment of his environment. Considered by many people more innocuous than sewage, suspended solid loads delivered to streams and lakes as sediment in surface runoff are equivalent by weight to more than 700 times the load from sewage. Sediment reduces water quality and often degrades deposition areas. Sediment pollutes when it occupies space in reservoirs, lakes, and ponds; restricts streams and drainageways; reduces crop yields in a given year; alters aquatic life in streams; reduces the recreational and consumptive use value of water through turbidity; and increases water treatment costs. Sediment also carries other water pollutants such as plant nutrients, chemicals, radioactive materials, and pathogens.

This paper does not encompass the entire problem, but does (a) identify problem areas, (b) define present understanding of the erosion and transport process, and (c) indicate research needs. The continuum from field erosion to streams is discussed, but primary emphasis is given to agricultural aspects of erosion and sedimentation in the humid central region of the United States. Only mechanical processes are considered; chemical and biological processes are omitted.

Although all approaches are used in erosion and sedimentation studies, the application of mathematical models to unsteady-state problems is only beginning. Most design approaches are based on field observations, and it is ironical in this time that most design is based on observation and not on Newtonian physics.

JOHNSON, L. D. 1976 (Jan). "Mathematical Model for Predicting the Consolidation of Dredged Material in Confined Disposal Areas," Technical Report No. D-76-1, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

From an investigation of various methods for sizing containment areas, suggestions are made for estimating containment area capacity based on consolidation of the dredged material and foundation soils.

The capacity of a containment area is defined herein as the total volume of the diked area available to hold dredged material. It is equal to the total unoccupied volume minus the volume associated with the freeboard. The capacity required to accommodate a given volume of in situ sediment to be dredged is related to the volume change characteristics of the sediment. For instance, the volume of sands and gravels deposited in the containment area usually does not change significantly with time and often is the same as, or only moderately more than, that of the in situ material. In contrast, the volume of silts and clays usually increases substantially on dredging and deposition. The subsequent consolidation of these materials can be substantial and lead to significant increases in space available in the containment area for placement of additional dredged material.

The volume-time relationships of dredged material are important in predicting the capacity of containment areas and also have considerable impact on subsequent use of deposition areas. Reasonably reliable estimates of the capacity require knowledge of the solids in the effluent water and evaluation of the time rate of change in void ratio of dredged material as it consolidates in the containment area. The usual containment area design does not consider time effects, but uses an empirical bulking factor that relates the volume of in situ sediments to the volume required in the containment area to place the same material. Experience indicates that bulking factors for this purpose vary from about one for most granular materials to as high as two for some fine materials, depending on local conditions. Values below one can occur for loose, granular material or fluffy, fine-grained deposits.

A tentative procedure is suggested for the estimation of the volume-time relationships of dredged material in a flooded containment area based on simple sedimentation and consolidation theories.

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KAMPHUIS, J. W., and HALL, K. R. 1983 (Jan). "Cohesive Material Erosion by Unidirectional Current," Journal of Hydraulic Engineering, Vol 109, No. 1, pp 49-61.

The initiation of motion of consolidated cohesive sediments under a unidirectional flow of clear water was studied. Experiments were performed in a flume-tunnel capable of providing a bed shear stress up to 26 Pa and a velocity of 3.5 m/sec, 3 mm above the bed. Samples were prepared in a specially designed press using a carefully controlled consolidation procedure. Critical shear stress and velocity were found to increase with compressive strength, vane shear strength, plasticity index, clay content, and consolidation pressure.

KANDIAH, A. 1974. "Fundamental Aspects of Surface Erosion of Cohesive Soils," Ph.D. Dissertation, University of California, Department of Civil Engineering, Davis, Calif.

Results of erosion tests carried out on remolded saturated soils using a rotating cylinder apparatus to study the mechanism of surface erosion by water and to establish empirical relationships between critical shear stress and key variables are presented.

It is postulated that surface erosion occurs particle by particle or aggregate by aggregate when the induced shear exceeds the critical shear stress. Further, migration of water into the soil and local swelling due to salt concentration gradient occur during the erosion process.

The Gouy double-layer theory is found to predict qualitatively the erosion behavior of cohesive soils. An exponential relationship between net energy of attraction and critical shear stress is observed, supporting the assertion that interparticle cohesion is a primary factor determining the resistance to erosion of clay soils.

The chemical composition of the pore fluid and pH are found to influence interparticle cohesion and hence affect the erosion rate and critical shear stress. Cation exchange capacity is significantly correlated to the critical shear stress. A parabolic relationship fits the observed data closely and a hypothesis based on edge-to-face and face-to-face bonding is proposed. A clay-quartz physical model is also proposed to explain the CEC-critical shear stress relationship. Cation exchange capacity is a measure of the total surface charge of the clay minerals and is intimately related to the properties of the diffuse layer. The CEC is related to interparticle cohesion and is shown to be a basic parameter governing the erodibility of a clay soil.

The effects of swelling, temperature, and organic matter on the critical shear stress are presented. Thermal effect on erosion seemed to obey rate process relations. Organic matter increased the resistance to erosion of flocculated soils and reduced the flaking rates of dried cohesive soils.

KARIM, F. M. 1981 (Dec). "Computer-Based Predictors for Sediment Discharge and Friction Factor of Alluvial Streams," Ph.D. Dissertation, University of Iowa, Ames, Iowa.

The primary objective of the study reported herein was to make use of the now rather extensive body of data available from flume experiments and rivers and of the enormous data-handling power of modern electronic computers, together with the understanding and formulations of the mechanics of sediment transport that have evolved over the years, to develop sediment-transport and friction-factor relationships for alluvial streams that are consistent with current comprehension of the roles of the dependent and independent variables in river flows. Predictors for sediment discharge by size fraction were also developed. Computer-based multiple-regression analysis was used to obtain quantitative relationships for use in river analysis and channel design.

The formulations developed in this study incorporate sediment discharge as an independent variable in the relations for friction factors of streams. The first and apparently only use of this concept heretofore was made in Blench's regime formulas. Blench, like other proponents and formulations of regime relations sought relations, among alluvial-stream variables by correlating, in graphical or mathematical formats, the relatively limited data then available. They first sought relations among variables from the data, then undertook to explain the forms of the relations they discovered.

The present study might be regarded as regime theory revisited in the company of the high-speed computer, modern computational methods, and a greatly expanded data base; and guided by fluid mechanics.

Two separate sediment-transport models were developed. The analytical foundations for the first one, the Suspended- and Bed-Load Transport Model (SBTM), are presented in Chapter II, which also describes the data base utilized and the computational analysis undertaken to obtain relationships for sediment-discharge and friction-factor. The development of the second formulation, the Total Load Transport Model (TLTM) is described in Chapter III. The formulation of a model to determine sediment discharge by size fraction and the results obtained from it are presented in Chapter IV. The friction-factor and sediment-discharge results obtained by means of SBTM and TLTM are presented in Chapter V, and compared statistically with those obtained from other relationships. Chapter VI summarizes the conclusions and recommendations. The appendices present a review of statistical methods utilized, description of alternative formulations for sediment-discharge and friction-factor predictors, and listing of basic data and of the computer programs.

KAVAZANJIAN, E., JR. 1975 (Sep). "Prediction of Void Ratio Vs. Depth at the James River Windmill Point Disposal Area," M.S. Thesis, Massachusetts Institute of Technology, Cambridge, Mass.

The objectives of this thesis are (a) to develop an analytical model for the prediction of the time-settlement relationship of a dredged fill and (b) to devise experimental procedures for determining the void ratio versus effective stress and coefficient of consolidation versus effective stress relationships for dredged material over the entire stress range likely to be encountered in a dredged fill.

Environmental considerations inherent to a marsh creation project require accurate determination of the final surface elevation of the dredged fill which is to subsequently become a marsh. Knowledge of the time necessary to attain that elevation is also desirable, to insure proper design and planning. To compute these quantities, both an analytical model and procedures to obtain the material properties required as input into the model must be developed. This thesis describes three laboratory sedimentation tests and a one-dimensional consolidation test.

KELLING, G., and STANLEY, D. J. 1978. "Sedimentation in Submarine Canyons, Fans, and Trenches: Appraisal and Augury," Sedimentation in Submarine Canyons, Fans, and Trenches, D. J. Stanley and G. Kelling, eds., Chapter 25, pp 377-388, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

The study of sedimentation in ancient and modern submarine canyons, fans, and trenches is in a state of explosive growth. A review of the principal milestones in the development of this research and an evaluation of factors providing the impetus for the expansion of interest in this field suggest that there are a number of elements that have facilitated this evolution. These include (a) revived recognition of the intimate relationship between sedimentation and structure, brought about largely by the new global tectonics concept; (b) clarification and refinement of some existing terms and concepts that resulted from imprecise appreciation of deep marine environments and sequences; (c) development of conceptual models that systematize the description and interpretation of deep marine sediment sequences; and (d) recognition of the remarkable variety of those sediment processes that operate beyond the shelf edge. The uneven development in understanding aspects of this complex area of research results from disparities both in economic pressures and in the technological capacity to test prevailing hypotheses. Studies of ancient sequences have significantly contributed to our present understanding of outer margin sedimentation. A shift in emphasis to modern equivalents, including trench and arc margin basins, is anticipated and is likely to provide a more balanced and truly actualistic approach and to generate new concepts. These trends are exemplified by the current interest in developing a more sophisticated view of the transportation mechanisms for sands and muds and in solving problems concerned with the occurrence of deep sea gravels.

KELLY, W. E., and GULARTE, R. C. 1981 (Oct). "Erosion Resistance of Cohesive Soils," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 107, No. HY10, pp 1211-1224.

An experimental study is described that concerned the surface erosion of an illitic silty clay (grundite) at selected salinities and water contents; the study was designed to test the applicability of rate process and double layer theories. Both velocity increment and temperature increment tests were run in a refrigerated water tunnel. Experimental activation energies and flow volumes were computed from test results. Values for experimental activation energies range from 14 to 32 kcal/mole, suggesting that interparticle contacts are essentially solid to solid as for soil deformation at higher stress levels. The mechanisms controlling resistance to surface erosion are fundamentally similar to the mechanisms controlling soil strength.

KENDRICK, M. P. 1972. "Siltation Problems in Relation to the Thames Barrier," Philosophical Transactions of the Royal Society of London, Mathematical and Physical Science Department, Vol 272, pp 223-243.

The problems confronting the Siltation Working Party of the Thames Flood Prevention Investigation are stated, the need for an early solution necessitated rigorous limitation of the possible combinations of site, function, and design of flood protection structure that could be studied. The reasons for excluding all schemes involving a permanent barrage are given, the Hydraulics Research Station (HRS) finally being asked to determine the effect on siltation of constructing a barrier at specified sites for use both as a simple surge excluding device and as a continuous half-tide control structure.

The methods adopted by HRS in tackling the problem are described. They include four large-scale estuarine surveys; the establishment of stations for continuously monitoring the suspended solids content of the river; field and laboratory tests to determine the properties of Thames silt; the development of a mathematical model to study the effect of the tide control on the distribution of silt which is carried in suspension; and experiments on a physical model to establish the redistribution of bed sediments in the navigation channel likely to follow barrier construction and continuous half-tide control.

The data from the field surveys demonstrate how current velocity, suspended silt concentration, salinity, and temperature at different depths along the estuary change throughout a spring and a neap tide during both high and low river flows. The results of the silt-monitoring exercise supplement the survey data by indicating how the concentrations of suspended sediment in the estuary vary--with tidal range, with position in the bimonthly spring-to-neap cycle and with seasonal variations in freshwater discharge. The tests to determine the properties of Thames silt provide values for the four parameters describing the processes of silt movement needed to develop the mathematical model.

The indications from the physical model studies are that the construction of a well-designed barrier used only to exclude surges should produce no insuperable siltation problems. Both mathematical and physical model results show that continuous tide control leads to increased siltation, the zone of greatest deposition depending on the barrier site.

KESTNER, F. J. T. 1966. "The Effects of Engineering Works on Tidal Estuaries," River Engineering and Water Conservation Works, R. B. Thorn, ed., Chapter 17, pp 226-238, Butterworths, London, England.

The general problems which an engineer meets in an estuary fall into three main groups: freshwater discharge, the safety and drainage of low-lying marshland, and navigation problems. It is difficult to pick a correct answer for any particular estuary and to know what side effects of any proposed engineering works may be. Two types of information have to be collected before any estimate can be made of the likely effects of any engineering work in an estuary. These are: first, the rise and fall of the tides at various points along the estuary from its mouth to its tidal limit through a neap/spring tidal cycle and secondly, information about the nature of the bed, the bed-load transport at different stages of the tide, and the suspended load and its deposition and subsequent erosion.

KIRBY, R. R., and PARKER, W. R. 1977. "The Physical Characteristics and Environmental Significance of Fine-Sediment Suspensions in Estuaries," Estuaries, Geophysics, and the Environment, pp 110-120, National Academy of Sciences, Washington, DC.

Detailed field investigations using new techniques in two contrasted European estuaries have revealed that the behavior of fine sediment is poorly understood and that laboratory simulations are unlikely to duplicate certain of the significant real-scale and time-dependent effects. The channels of the Severn are the site of mobile dense suspensions and ephemeral static suspensions on springs and more stable dense static suspensions on neaps. A sequence of structures develops in response to changes in energy levels on the semidiurnal and spring-neap time scale. In contrast, in the Maas dense mobile suspensions and static suspensions have been identified whose development has little apparent relation to any tidal time scale. It may be that only a one-way movement of dense near-bed suspension occurs in the Maas.

Despite the great contrasts in physical character, both estuaries studied show temporally and spatially complex and stratified suspensions, and it may be that similar structures are common in other estuaries. In both estuaries, dense mobile suspensions are thought to play an important role in the sediment circulation.

Future work is being directed toward a quantitative description of fine-sediment phenomena and to field investigations of the processes governing their behavior. When the phenomena themselves are adequately understood and the processes responsible for them are adequately identified and scaled, the resulting realistic models will form the basis from which predictive models of estuarine sediment circulation and fine-sediment behavior may be developed.

KJERFVE, B., STEVENSON, L. H., PROEHL, J. A., CHRZANOWSKI, T. H., and KITCHENS, W. M. 1981. "Estimation of Material Fluxes in an Estuarine Cross Section: A Critical Analysis of Spatial Measurement Density and Errors," Limnology and Oceanography, Vol 26, No. 2, pp 325-335.

Estuarine budget studies often suffer from uncertainties of net flux estimates in view of large temporal and spatial variabilities. Optimum spatial measurement density and material flux errors for a reasonably well-mixed estuary were estimated by sampling 10 stations from surface to bottom simultaneously every hour for two tidal cycles in a 320-m-wide cross section in North Inlet, South Carolina. Discharge and material fluxes were computed. The analysis method was to form a number of cases, each based on a different number and combination of stations, and compare these fluxes to the ideal case using all 10 stations. A percentage error (rms derivation of a given case from the ideal case compared to the tidal prism) was <15 percent with only three lateral stations, each located to cover a separate bathymetric regime. In estuaries with dimensions similar to North Inlet, these results should prove useful in selecting an optimum (or minimum) number of required stations.

KLEIN, G. D. 1967. "Comparison of Recent and Ancient Tidal Flat and Estuarine Sediments," Estuaries, G. H. Lauff, ed., Publication No. 83, pp 207-218, American Association for the Advancement of Science, Washington, DC.

The purpose of this paper is to determine what features of modern tidal flats and estuarine sediments are preserved in their ancient counterparts. After these features are identified and distinguishing criteria become established, it should be possible to improve our genetic interpretation of ancient sedimentary rocks.

Tidal flat sedimentation can occur along soft-sediment coasts and along bedrock coasts. Each of these areas generates its own sequence of sediments and environments. These two types of tidal flat are designated by the author as Wadden-type and Fundy-type, respectively.

Ancient tidal flat deposits have been described from the Upper Devonian of Belgium, the Lower Devonian of England, and the Pennsylvanian of Illinois. Carbonate tidal flat sediments occur in the Middle Jurassic rocks of England.

Estuarine sedimentation is dominated by a circulation plan involving the influx of a salt wedge during high tide and the retreat of such a salt wedge during low tide. This pattern is superimposed on tidal channel, tidal marsh, lagoon, river, and deltaic environments. River estuaries are characterized by sedimentary vertical sequences consisting of a basal lag concentrate of clay pebbles, marine shells, and peat fragments, overlain by cross-stratified sands and capped by flat-bedded, rippled sands, and clay laminae. They record the predominance of upper-flow regime during bank erosion and lower-flow regime during sediment deposition.

Ancient counterparts to estuaries are believed to have existed, because of the studies of the Coal Measures of Pennsylvania and the Berea Sandstone of Ohio. The Middle Jurassic Great Estuarine Series of Scotland and England represent lagoonal environments on which an estuarine circulation system may have been imposed. Deposition of evaporites in the geological past took place in mixed shallow marine environments and required an estuarine circulation system in an arid climate to supply continuously the large volume of water from which salt was precipitated.

KLINGEMAN, P. C., and KAUFMAN, W. J. 1965 (Sep). "Transport of Radionuclides with Suspended Sediment in Estuarine Systems," Sanitary Engineering Research Laboratory Report No. 65-15, University of California, Berkeley, Calif.

The present research concerned that distinct aspect of radioactive waste behavior dealing with the transport of radionuclides with suspended sediment in estuarine systems. In scope, this investigation dealt with the changing distribution of radionuclides in the waters and sediments of a river-estuary system and with the factors effecting these changes. The broad purposes of this research were (a) to establish the degree of association of fission radionuclides with suspended river particulates, (b) to determine the influence of the saline estuarine environment on this association, and (c) to ascertain the fundamental relationships that influence the transport and deposition of these particulates in an estuarine system. Particular emphasis was given to fission products of recent fallout origin. Because of the "fortuitous" labeling of large masses of river suspended sediment by the fission products of fallout, it was feasible to follow the transport, deposition, and redistribution of recent river suspensions within portions of the San Francisco Bay system.

KNEBEL, H. J., CONOMOS, T. J., and COMMEAU, J. A. 1977 (Mar). "Clay-Mineral Variability in the Suspended Sediments of the San Francisco Bay System, California," Journal of Sedimentary Petrology, Vol 47, No. 1, pp 229-236.

Semiquantitative determinations of the clay-mineral composition have been made on nearly synoptic samples of surface suspended sediments collected seasonally throughout the San Francisco Bay system. The relative amounts of chlorite + kaolinite are generally highest in the northern reach of the system, whereas illite is dominant in the southern reach. The proportion of montmorillonite is low throughout the bay. Time-series and replicate samples collected at individual stations show that the difference in clay-mineral content between reaches is real and reflects a change in the source of clay-mineral particles within the bay. The Sacramento-San Joaquin river system supplies the northern reach, whereas most clay-mineral particles come from resuspension by waves and tidal currents in the southern reach. Analyses of bottom sediments and the spatial variability in the northern reach suggest that the relationship between the abundance and sources of clay minerals may, in turn, be a function of particle size. This study demonstrates the utility of suspended clay minerals in the interpretation of sediment-dispersal patterns in estuaries.

KNIGHT, R. J., and DALRYMPLE, R. W. 1975. "Intertidal Sediments from the South Shore of Cobequid Bay, Bay of Fundy, Nova Scotia, Canada," Tidal Deposits, R. N. Ginsburg, ed., Section I, Chapter 6, pp 47-55, Springer-Verlag, New York.

The vertical sequence represents a simple hypothetical regressive composite of the various environments in the study area. The proposed sequence assumes that sufficient sediment is available to cause the eventual infilling of the bay and does not necessarily represent any present vertical succession in the area. The sequence assumes almost complete preservation of sandbars as indicated by the nine meters of cross-stratified sands.

The sequence generally fines upward, reflecting a transition from the relatively high-energy lower intertidal and subtidal environments to the lower energy conditions of the upper intertidal and supratidal zones. The sediments are cut by a series of incised channels that may or may not show any trough cross stratification due to sideways infilling, but may exhibit scoured-erosional bases and channel outlines overlain with a coarser sediment lag that fines upward and that may itself be cross stratified.

KOMAR, P. D. 1981 (Dec). "The Applicability of the Gibbs Equation for Grain Settling Velocities to Conditions Other Than Quartz Grains in Water," Journal of Sedimentary Petrology, Vol 51, No. 4, pp 1125-1132.

Gibbs and others have derived empirical equations that yield settling velocities in water for spherical grains of approximately quartz density. The present investigation examines the applicability of their relationships to other grain densities and fluids and to gravity fields other than Earth's. The comparison is with "data" generated from a standard drag coefficient versus Reynolds number curve that is applicable to the settling of spheres in any Newtonian fluid. This comparison shows that the relationships cannot be used for gravity fields other than Earth's or for fluids other than water, in each case the errors being extreme. Their relationships do yield good results over the range of grain densities represented by the common heavy minerals settling in water. As the density progressively departs from that of quartz, the amount of error increases, reaching 8.5 percent for densities as high as magnetite. A correction factor is introduced which is a function of grain density, the use of which greatly improves the estimated settling velocities of the common heavy minerals and of low-density materials such as foraminifera shells.

KOUTITAS, C., and O'CONNOR, B. 1980. "Numerical Modelling of Suspended Sediments," Advances in Water Research, Volume 3, pp 51-57.

The turbulent advection-diffusion mathematical model in three-dimensional space is solved by a mixed finite element finite difference method. Linear finite elements in the vertical direction and central finite differences in the horizontal directions are used coupled with the Galerkin error minimization procedure. The integration in time is performed in fractional steps (one explicit one implicit) by splitting the differential operator. The method is illustrated by application to the three-dimensional movement of suspended sediment. Its accuracy is checked by comparison to analytical solutions, and its efficiency is gauged relative to finite elements and implicit finite difference solutions for two-dimensional suspended sediment transport over a dredged channel.

KRAFT, J. C., and ALLEN, E. A. 1975. "A Transgressive Sequence of Late Holocene Epoch Tidal Environmental Lithosomes Along the Delaware Coast," Tidal Deposits, R. N. Ginsburg, ed., Section I, Chapter 5, pp 39-46, Springer-Verlag, New York.

A study of holocene coastal sedimentary environments provides a direct key to the interpretation of sediments deposited in coastal and nearshore marine environment of the Atlantic continental shelf. Sequences of sediments and patterns and distributions of sedimentary structures can be used to form models for the interpretation of transgressive sequences along the entire Atlantic Coast.

KRANCK, K. 1979. "Dynamics and Distribution of Suspended Particulate Matter in the St. Lawrence Estuary," Le Naturaliste Canadien, Vol 106, pp 163-173.

Spot samples and tidal cycle anchor stations throughout the estuary from Pointe des Monts to Lake St. Pierre are used to map concentrations, grain size, and weight/volume ratios of suspended particulate matter. Their distributions are related to physical factors (salinity, currents, and depths) and to bottom samples. A turbidity maximum maintained by tidal current asymmetry and flocculation dominates the upper estuary. Preferential deposition of organic as opposed to inorganic particles in the turbidity maximum depletes the particulate matter of organic matter and associated potential pollutants between the river and the seaward parts of the estuary. The lower estuary has a normal open coastal three-layer stratification of particulate matter. Bottom sediments reflect the concentration and flocculation state of sediment in the waters above.

KRANCK, K. 1980. "Experiments on the Significance of Flocculation in the Settling of Fine-Grained Sediment in Still Water," Canadian Journal of Earth Sciences, Vol 17, No. 11, pp 1517-1526.

The changes in grain size and concentration with time were studied in relatively dilute settling suspensions of varying initial concentration and constituent grain size and composition. During single-grain settling in distilled water and dispersant solution, i.e., in the absence of flocculation, a narrow range of sizes at a time was lost from suspension at a rate dependent on the initial size distribution. In salt water, the importance of single-grain settling relative to floc settling decreased with increase in concentration. The decrease in total concentration with time due to floc settling was proportional to the minus four-thirds power of the time. The overall sorting of the sediment had some effect on the flocculation rate, but the effect of grain mineralogy appeared to be minor. Comparison between the size distributions of the settled sediment and textures of recent clastic sediments and experimental turbidites indicates that the relative effectiveness of single grain and floc settling largely determines the sorting of most fine-grained as well as many sandy sediments.

KRANCK, K. 1973 (Dec). "Flocculation of Suspended Sediment in the Sea," Nature, Vol 246, pp 348-350.

Suspended samples were taken in coastal areas, analyzed for size and concentration, and visually inspected. Concentrations ranged from 0.5 to 20 ppm, and mode size ranged between 6 and 20 micrometers. Size did not change after months of storage. Vigorous agitation did not change the size distributions. Flocs were coated with organics and were loose aggregations of biogenic, inorganic, and organic material. Size distribution of inorganic fraction was determined by: filtering 500 ml, ashing the filter, suspending in 2 percent Calgon (3 percent saline), subjecting to sonic dismemberment, and analyzing by Coulter counter. Volume concentration was reduced by half. Good correlation was found between the original and elemental size mode. There was no correlation between size and concentration, but a distinct relationship was noted between size and current speed. Characteristic size distribution is suggested, the mode depending on constituent grains. As flocs become larger, they are subjected to more shear. A bigger increase in grain mode is needed as floc size increases to insure stability.

KRANCK, K. 1981. "Particulate Matter Grain-Size Characteristics and Flocculation in a Partially Mixed Estuary," Sedimentology, Vol 28, No. 1, pp 107-114.

The concentration and grain size of the natural and deflocculated inorganic suspended particulate matter were measured along the length of the Miramichi estuary and interpreted with respect to flocculation and transport properties. Changes in particulate matter concentration are associated with regular changes in grain-size characteristics. In the turbidity maximum region of the estuary, the suspended matter occurs mostly as large flocculated particles whereas, in the waters with lower particle concentrations, a larger proportion of the material occurs as fine material. At higher concentrations natural floc modes and inorganic grain modes vary simultaneously, but at low concentrations the two modes vary inversely. This modal relationship and the variation in organic matter within the estuary are proposed to result from variation in inorganic-organic composition of flocs. Increase in settling rates due to flocculation is believed to increase the trapping effect of the estuarine circulation that produces the turbidity maximum.

KRANCK, K. 1974 (May). "The Role of Flocculation in the Transport of Particulate Pollutants in the Marine Environment," Proceedings, International Conference on Transport of Persistent Chemicals in Aquatic Ecosystems, pp I-41 thru I-46.

Suspended particulate matter in a marine environment forms aggregates or flocs the size of which are controlled by the size of the original constituent grains. Flocculation increases the settling speed of the particulate matter, thereby increasing the difference between the transport rate of the particles and that of the water in which they are suspended. The behavior of particulate pollutants in a natural marine environment was studied by laboratory simulation of flocculation and by studying particle distributions in two areas with high concentrations of industrial particulate effluent. The results show that pollutant particles flocculate in a manner similar to that of a natural sediment, and the transport and distribution of the natural sediment are a guide to the transport and dispersal of effluent particles.

KRANCK, K. 1975. "Sediment Deposition From Flocculated Suspensions," Sedimentology, Vol 22, No. 1, pp 111-123.

Suspended sediment in coastal environments with high inorganic content have characteristic broad size distributions and are composed of both single grains and flocculated aggregates. These flocculated suspensions have stable size distributions the modal size of which is dependent on the modal size of the deflocculated single grain distributions. Comparison between theoretical settling speeds of quartz grains and the settling speed of particles in natural suspensions indicates that most grains smaller than the deflocculated single grain mode settle as part of flocs, whereas the particles larger than the mode settle as single grains. As a result the size distribution curves of sediment populations which settle out during consecutive intervals are composed of a modal peak of larger grains and a low flat portion of smaller grains and resemble the asymmetrical nonnormal curves common for muddy sediments.

KRANCK, K. 1972 (Sep). "Tidal Current Control of Sediment Distribution in Northumberland Strait, Maritime Provinces," Journal of Sedimentary Petrology, Vol 42, No. 3, pp 596-601.

In Northumberland Strait, muddy sediments are being deposited in areas with maximum tidal current speeds (amplitude of M_2) of less than 0.5 knots, while sands and gravels occur in areas where currents are stronger than this. There is a direct relationship between the median diameter of bottom sediments and maximum tidal current speeds. Tidal current asymmetries occur such that the speed and duration of the ebb and flood currents differ. Two types of asymmetries are distinguished: Langrangian and Eulerian. Tidal current asymmetries and the presence of a residual current cause a difference in the amount of sediment transported in the ebb and in the flood direction and hence a net sediment transport.

KRANCK, K., and MILLIGAN, T. 1980 (Jul). "Macroflocs: Production of Marine Snow in the Laboratory," Marine Ecology Progress Series, Vol 3, pp 19-24.

Large suspended aggregates similar to "marine snow" have been obtained by placing natural and artificially produced particulate matter in a vertical recirculating tube with an upward flowing turbulent current. At flow rates as high as 0.25 cm s^{-1}, the seawater suspension settled out as *macroflocs* which incorporated all the components in suspension. The size and shape of the particles produced by physiochemical flocculation varied with flow rate and floc composition.

KRIEGER, I. M., and DOUGHERTY, T. J. 1959. "A Mechanism for Non-Newtonian Flow in Suspensions of Rigid Spheres," Transactions of the Society of Rheology, Vol III, pp 137-152.

A mechanism is postulated to account for non-Newtonian flow in suspensions of rigid spheres. On the basis of this mechanism, the flow equation $(\eta - \eta_\infty)/(\eta_o - \eta_\infty) = (1 + |\tau/\tau_c|)^{-1}$ is derived, where η is the viscosity at the shear stress τ , η_o and η_∞ are the limiting values of η at zero and infinite shear, respectively, and τ_c is a parameter determined by temperature and particle size. This equation correlates well with published data on latex and polymer systems. For latex suspensions, the parameter τ_c does not depend on concentration and for these systems the dependence of the relative viscosity at a fixed shear stress, η_r , on volume fraction of suspended phase, ν , is accurately described by the equation $\ln \eta_r = -\rho[\eta] \ln (1 - \nu/\rho)$, where $[\eta]$ is the intrinsic viscosity and ρ is the volume fraction at close-packing. In general, the parameters $[\eta]$ and ρ depend on the shear stress.

KRIZEK, R. J., ATMATZIDIS, D. K., and FITZPATRICK, J. A. 1977 (Nov). "Characteristics of Dredged Bottom Sediments," Journal of the Waterway Port Coastal and Ocean Division, Vol 103, No. WW4, pp 471-486.

Information on grain-size distributions and seven chemical constituents of dredged bottom sediments for a large number of locations from all geographic regions of the United States has been collected and presented in a compact form. These data were accumulated for a wide range of candidate dredgings over a period of approximately six years, during the time that Jensen criteria for open water disposal of dredged materials were in force. Although presently unjustified as the sole criteria for judging the acceptability of dredged or fill material discharges, bulk parameters may help to evaluate probable environmental impacts of proposed operations and thus serve as a guide in categorizing dredged bottom sediments. The reported grain-size distributions of bottom sediments are believed to cover the range of gradations that will likely be encountered during dredging and disposal operations. This information can be highly useful in studies to predict sedimentation patterns and extent.

According to the empirical bulk analysis criteria, most of the sediments from approximately fifty locations in the United States would be termed polluted. The grain-size distributions of dredged bottom sediments were found to vary significantly with location, but the usefulness of some test data is limited by inappropriate test procedures. In particular, grain-size analyses should be performed without the use of a dispersing agent to more realistically reflect the conditions that exist in the field. The hydrodynamic behavior and settling characteristics of dredged sediments will be influenced strongly by whether they are flocculated or dispersed; this should affect sediment chemical uptake or release to a lesser extent. Although some correlations between chemical constituents and the characteristics of dredged bottom sediments were found to exist, additional data are needed to advance broader and more definitive conclusions regarding the water-quality impact that might occur during dredging and disposal operations. The results of a simple bivariate regression analysis suggest that trace amounts of zinc and lead are associated with petroleum residues, whereas mercury is adsorbed to fine-grained sediments as an organic complex.

KRONE, R. B. 1978. "Aggregation of Suspended Particles in Estuaries," Estuarine Transport Processes, B. Kjerfve, ed., No. 7, pp 177-190, University of South Carolina Press, Columbia, SC.

Although it is evident that fine particles are transported long distances in streams and then deposited in estuaries, the extent that deposition is due to increased settling velocities that result from aggregation of the fine particles in a saline environment or to the change in hydraulic conditions has not been established. This paper describes (a) conditions required for aggregation of suspended particles; (b) shear strengths of aggregates; and (c) densities of aggregates, to show that aggregation and disaggregation by local hydraulic conditions alter the transport properties of suspended particles.

KRONE, R. B. 1972 (Jun). "A Field Study of Flocculation as a Factor in Estuarial Shoaling Processes, Appendix D: Velocities, Salinities, and Suspended Solids from Field Measurements and Samples," Technical Bulletin, No. 19, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This appendix presents the handwritten field data sheets of velocities, salinities, and suspended solids from field measurements and samples.

KRONE, R. B. 1962 (Jun). "Flume Studies of the Transport of Sediment in Estuarial Shoaling Processes" Hydraulic Engineering Laboratory and Sanitary Engineering Research Laboratory, University of California, Berkeley, Calif.

Early in the course of development of a method for tracing sediment movement in San Francisco Bay, two facts regarding bay sediments were confronted: (a) in nearly every problem area within the bay system, the sediments participating in shoaling consist largely of clays, and (b) information on the nature of transport and deposition of these sediments was almost entirely speculative. The sediments were loosely termed "silt" or "mud," the former possibly because the particle size distribution analysis method used was in error toward the coarser sizes and the latter because it best describes the appearance of the deposited sediment. An appreciation of the clay fraction and its significance depended on knowledge of its abundance. Sediment transport and shoaling processes were considered to consist of flocculation in regions where sea water mixed with river water, followed by deposition of the flocs in nearby tranquil areas, or transport near the bed as "fluid mud" along the bottom into a shoaling area, where it consolidated.

A need for knowledge of shoaling and transport processes of San Francisco Bay sediment was indicated by the cost of maintenance of navigable water depths in channels and harbors in the system. Annual dredging costs exceeded two million dollars. To reduce this continuing cost, the San Francisco District undertook the study of means for reducing sedimentation in maintained areas and for improving the efficiency of maintenance operations. The development of a method for tracing sediment movement was a part of this study. Its purpose was to overcome the difficulties of direct observation of estuarial sediment transport and to facilitate acquisition of information leading to design of improved works and maintenance operations.

KRONE, R. B. 1979. "Sedimentation in the San Francisco Bay System," San Francisco Bay: The Urbanized Estuary, The Pacific Division of the American Association for the Advancement of Science, California Academy of Sciences, San Francisco, Calif.

Sediment inflows to the San Francisco Bay system have been significantly affected by man since the 1860's. Mining and agriculture caused large increases in sediment inflows during the late 1800's, and rapidly increasing freshwater diversions for irrigation are now causing depleted sediment inflows. In addition, maintenance dredging within the system alters sediment transport.

Sediments entering the system with land drainage consist largely of silts and clay minerals. These materials enter with high winter river flows and settle initially in the upper bays. Daily spring and summer, onshore winds generate waves that suspend fine materials and hold them in suspension while tidal- and wind-driven currents circulate the suspended material throughout the system and to the ocean.

The effectiveness of waves in suspending deposited material increases rapidly with decreasing water depth. As the upper bays fill with sediment to depths where wave action resuspends the annual load at the same rate as the supply, the water depths tend to remain constant there, and further accumulation of sediment in the system occurs seaward. Evaluation of historical bathymetric surveys, including the effects of rising sea level, shows progressive sedimentation in the system that is now approaching Central Bay. Future freshwater diversions will materially slow this trend and will cause reduced turbidity from sediment particles.

KRONE, R. B. 1963. "A Study of Rheological Properties of Estuarial Sediments," Technical Bulletin No. 7, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Sediments from deposits in several representative estuaries were examined for mineral content and particle size distribution and were found to contain large amounts of clay minerals. The clay mineral composition varied among the sediments in relative abundance of the principal minerals montmorillonite, kaolinite, and illite. The clay minerals account for the cohesive character of the sediments studied, and their relative abundances determine the porosities and strengths of aggregations of the mineral particles.

The porosities and shear strengths of sediment aggregations were obtained from measurements of rheological properties of suspensions over a range of sediment concentrations, and at varying shearing rates. An Ostwald-type capillary viscometer, equipped with variable driving pressures, was used for measurements at high shearing rates, and a concentric cylinder viscometer with a wide annular gap was constructed for measurements at low shearing rates.

Interpretation of the data from the rheological measurements was facilitated by Bingham's hypothesis and Einstein's viscosity relation. A relation was derived by H. A. Einstein based on Bingham's hypothesis for relating the drag and rotation speeds in a wide-gap concentric cylinder viscometer to the shear strength and differential viscosity of a suspension. Separation of fluid from solid friction by Bingham's hypothesis allowed separate interpretations of shear strengths of the suspended aggregates and of the viscosities of the suspensions. Einstein's relation, derived for an infinitely dilute suspension, was extended to a logarithmic form to accommodate the concentrations of suspended particles of interest to this study. The data support the extension, and with it was obtained information on densities and porosities of sediment aggregates. Both the shear strengths and the densities of the suspended aggregates of estuarial sediments were thereby obtained.

Measurements with the wide annular gap concentric cylinder viscometer showed that each of the suspended sediments can aggregate in several ways, depending on the shearing rate and the history of the suspension. A description of aggregates was devised that is based on the concept of combinations of simple aggregations of primary mineral particles. When such clusters of mineral particles, designated zero order aggregates, combine with one another they form first order aggregates that have larger volume or lower density because of the pore spaces between the zero order aggregates. Second order aggregates, formed by combination of the first order aggregates, have an even lower density.

KRONE, R. B. 1976. "Ultimate Fate of Suspended Material in Estuaries," Proceedings of the Specialty Conference on Dredging and Its Environmental Effects, American Society of Civil Engineers, pp 180-201, Mobile, Ala.

Knowledge of the transportation of estuarial sediments and their ultimate fate is needed for the management of activities that affect estuarial water quality. This paper presents a qualitative description of the transport and ultimate fate of estuarial sediments and identifies the factors relevant to the management of dredged spoil disposal activities.

KRUMBEIN, W. C., and ABERDEEN, E. 1937 (Apr). "The Sediments of Barataria Bay," Journal of Sedimentary Petrology, Vol 7, No. 1, pp 3-17.

Ninety-eight bottom samples were collected from Barataria Bay, on the margin of the Mississippi delta, in accordance with a predetermined grid pattern. Mechanical analyses were performed, and the several statistical constants of the samples computed. Maps were prepared showing the aerial distribution of the samples in terms of their average size and their "degree of sorting"; this distribution was related to the currents within the bay. In all, five main types of sedimentary curves were found, which displayed a regular variation in character from deeper to shallower parts of the bay.

KUENEN, P. H. 1968. "Settling Convection and Grain-Size Analysis," Journal of Sedimentary Petrology, Vol 38, No. 3, pp 817-831.

Grain-size analysis by settling techniques presupposes free sinking of the particles. There are two phenomena that might have an adverse effect on this basic assumption. The first has been termed "hindered settling" and denotes the obstruction that settling particles experience from the upward flow around neighboring grains. This influence will not be considered here. Another phenomenon, that I have called "settling convection," signifies the current system set up by differences in density of clouds in a settling suspension. The two processes are normally combined. The action of the latter strongly varies according to conditions. Bradley's "vertical density currents" form a border case. In suspensions prepared for pipette analysis, it develops lively small-scale currents. Tests are presented to show that the influence on the deduced size distribution is fortunately negligible and roughly equivalent to heating by 1 degree centigrade. In salt water-clay suspensions and various other mixtures of solids with liquids, the action of settling convection helps to preserve a uniform suspension below a steadily sinking interface. At the bottom, there exists a rising boundary between the suspension and the deposit. This constant composition excludes the possibility of grain-size analysis in sea water by means of the settling velocity of the separate particles. A rough alternative visual method for size analysis of flocculated suspension is described.

Sedimentation balances for size analyses of silt and clay employing a shaken suspension suffer the same slight acceleration as pipette analyses. Moreover, the convection around the submerged dish forms a serious drawback to this technique.

Settling convection tends to augment the sinking velocity of sand grains released at the surface, especially in samples with a narrow range in size and also for particles of less than 0.1 to 0.05 mm. Hence, the usefulness of various types of sedimentation analyzers based on sample introduction from above is restricted to sizes above 50 microns. Settling convection also renders ineffective counter-current methods (elutriators) in water. Elutriation in air is inapplicable for lutum samples that have been wet, hence for most natural sediments except colian deposits.

KUSUDA, T., UMITA, T., KOGA, K., YOROZU, H., and AWAYA, Y. 1982. "Depositional Process of Fine Sediments," Water Science Technology, Vol 14, pp 175-184.

The main purposes of this study were to investigate the depositional properties of the typical fine less-cohesive sediments in Japanese estuaries and bays and to make it possible to estimate the amount of deposition of the sediments. Suspended fine sediment concentration depends strongly on the shear stress and a critical particle diameter exists corresponding to a certain shear stress. The suspended particles larger than the critical diameter settle down proportionally to the concentration of particles. On the other hand, the suspended particles smaller than the critical diameter are held in water without settling. The depositional properties obtained from experiments make it possible to estimate the depositional rate and amount of the sediments. In the laboratory experiments on deposition, an annular flume with a ring and a channel was used.

KYNCH, G. J. 1952. "A Theory of Sedimentation," Faraday Society Transactions, Vol 48, pp 166-176.

The theory assumes that the speed of fall of particles in a dispersion is determined by the local particle density only. The relationship between the two can be deduced from observations on the fall of the top of the dispersion. It is shown that discontinuous changes in the particle density can occur under stated conditions.

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LANE, E. W., and KOELZER, V. A. 1943 (Nov). "Density of Sediments Deposited in Reservoirs," Report No. 9, US Army Engineer District, St. Paul Sub-Office, Hydraulic Laboratory, University of Iowa, Iowa City, Iowa.

In order to determine the rate at which reservoirs will fill with sediment, it is often necessary to estimate the weight per unit volume of the deposited sediment, because the quantity of sediment carried by a stream is usually expressed in terms of weight rather than volume. A thorough study of this subject has never been undertaken and consequently the estimated densities used cover a wide and indiscrimate range of values. All available data have been compiled in this report. The results and conclusions drawn from an analysis of the data are summarized in a form applicable to the needs of organizations or individuals interested in reservoir design.

LARSONNEUR, C. 1975. "Tidal Deposits, Mont Saint-Michel Bay, France," Tidal Deposits, R. N. Ginsburg, ed., Section I, Chapter 3, pp 21-30, Springer-Verlag, New York.

The Bay of Mont Saint-Michel is deep inside the gulf of Saint-Malo in the western part of the English Channel, between Brittany and the Cotentin Peninsula. It constitutes a wide-open basin slanting regularly toward the northwest and opening on to the sea along a distance of 20 km, between the Pointe du Grouin and the cliffs of Carolles. The elegant outline of Mont Saint-Michel towers above the bay, which is characterized by an exceedingly wide beach (up to 15 km) furrowed by a shifting dendritic pattern of channels at low tide. Toward the south, it merges into some low coastal lands reclaimed from the sea and now cultivated: the Dol marshes, the polders of Mont Saint-Michel.

LAURSEN, E. M. 1957 (Jun). "An Investigation of the Total Sediment Load," Office of Naval Research, Navy Department, Washington, DC.

Through the use of (a) a qualitative analysis, (b) original experiments of a specialized nature, and (c) supplementary data from other sources, empirical relationships for the primary aspects of the sediment load have been obtained. These relationships permit the composition and the rate of transport of the total load, the suspended load, and the bed load to be evaluated from the hydraulic characteristics of the stream (mean velocity and depth of flow and energy gradient) and the characteristics of the bed sediment (frequency distribution of size and fall velocity).

In the process of defining the relationships between the parameters which were found to govern the sediment loads, a correlation of laboratory data representing a ten-thousand-fold range in rate of transport was obtained with a scatter probably not much greater than the error in the experimental observations. The extent to which the proposed relationships could predict field conditions was demonstrated for three natural streams. The degree of approximation was especially encouraging, since this is the ultimate goal of the search for a general sediment-transport function.

LEAN, G. H. 1980. "Estimation of Maintenance Dredging for Navigation Channels," Hydraulics Research Station, Wallingford, England.

With the increasing size and draught of ships, port authorities are concerned with the cost of increasing the depths and widths in their access channels and dock areas, which includes the initial dredging cost and the continuing charges for maintaining the new dimensions. In the present report, attention is confined to the methods which can be used to predict maintenance dredging and is further restricted to those parts of the access channels which are situated in the outer parts of estuaries and offshore. Similar problems are encountered in the more sheltered areas inshore but here other factors such as the effect of littoral drift along the coast, the current pattern caused by the local geometry of the bed and shoreline, and current drifts due to salinity and their inter-relationship with the enlarged channel make it impossible to give any general statement about channel infill; such cases must be treated individually.

LEE, D. Y. 1979 (Aug). "Resuspension and Deposition of Lake Erie Sediments," M.S. Thesis, Case Western Reserve University, Department of Mechanical and Aerospace Engineering, Cleveland, Ohio.

An experimental investigation of the resuspension and deposition characteristics of four types of sediments from the Western Basin of Lake Erie has been made. The experiments were conducted in a rotating, circular flume in which a turbulent flow exerted a shear stress on the sediment-water interface. The flow velocities were measured by means of a hot film anemometer. Concentrations of suspended sediment were monitored by a turbidity meter and direct sampling.

Experiments performed were entrainment, deposition, and entrainment followed by deposition. Entrainment and deposition rates were found as a function of the applied shear stress, water content, and mineralogy. The entrainment-followed-by-deposition experiment showed a strong hysteresis phenomena. The distribution of settling velocities was also measured and showed a wide range of settling velocities, indicating a wide range of effective particle sizes. This plus the varying mineralogy indicated a wide range of particle properties, a fact needed in the interpretation of the experiments.

LEE, P. T. 1974. "Deposition and Scour of Clay Particles Due to Currents," M.S. Thesis, No. 650, Asian Institute of Technology, Bangkok, Thailand.

Incipient motion of bottom sand due to waves and currents has been extensively studied by several researchers, while that of clay is not yet clearly understood although it is very important in estuaries in deltaic areas where they cause changes in flow patterns, create navigational hazards, and require expensive dredging.

The critical shear stress for deposition of clay sediments was determined by using a paddle-type, recirculating flume for various salinities. The sediment samples and sea water used in the experiments were taken from the neighborhood of Bandon Harbor, Surat Thani Province, Thailand. A few sets of experiments for the scouring process were also conducted.

LEEDER, M. R. 1983. "On the Dynamics of Sediment Suspension by Residual Reynolds Stresses--Confirmation of Bagnold's Theory," Sedimentology, Vol 30, pp 485-491.

Bagnold's dynamic theory for sediment suspension requires that the immersed weight of suspended grains over unit bed area is supported by an upward-directed residual Reynolds stress, τ_{yy}, arising from asymmetrical shear turbulence. The present paper presents an analysis of previously published turbulence data which confirms the existence of this residual stress and indicates its generation in the lowermost part of the buffer layer of turbulent shear flows. The magnitude of τ_{yy} is estimated as about $0.3\tau_{yx}$. Calculations from experimental data on suspended fine sand transport over upper phase beds reveals that τ_{yy} is in approximate equilibrium with the weight stress due to the suspended load.

LEWIS, R. R., III. 1976 (Nov). "Impact of Dredging in the Tampa Bay Estuary 1876-1976," Proceedings, Second Annual Coastal Society Conference, pp 31-55, New Orleans, La.

Tampa Bay is an estuary located on the west coast of Florida. One-sixth of the state's population lives in the three counties bordering its shores.

During the last 100 years, four major types of dredging have impacted the bay: channel deepening, maintenance dredging, shell dredging, and dredging for landfill construction. These impacts range from the economic benefit provided by channel and port construction for what is now the eighth largest port in the nation to the environmental damage caused by dredging to create over 5,000 hectare of landfill in the bay for residential, commercial, and dredged material disposal use. These landfills have resulted in the loss of 44 percent of the original marine wetlands bordering Tampa Bay.

Recent environmental concerns have halted landfill dredging and severely restricted maintenance dredging. Research on shell dredging in the bay indicates minimal impact if carefully controlled. New channel deepening and open water disposal of 55,000,000 m^3 of dredged material is planned as part of the Tampa Harbor Deepening Project, now in progress. This project has undergone intensive review and modification as a result of environmental concern by both citizens and scientists.

LIN, P., HUAN, J., and LI, X. 1983. "Unsteady Transport of Suspended Load at Small Concentrations," Journal of Hydraulic Engineering, American Society of Civil Engineers, Vol 109, No. 1, pp 86-98.

When suspension is the predominant mode of sediment transport, an expression for the rate of bed changes may be introduced. This equation together with the momentum equation and the continuity equations of water and sediment constitute a set of four equations for four unknowns. Characteristic directions can then be determined without solving a high-degree algebraic equation. The solution is further simplified by adopting a small-concentration approximation. Routing of suspended load with this method is applied to the Qiantang estuary in eastern China and rather close simulation has been achieved.

LIOU, Y. D. 1970 (Aug). "Hydraulic Erodibility of Two Pure Clay Systems," Ph.D. Dissertation, Colorado State University, Fort Collins, Colo.

A specially designed laboratory erosion device was developed to define more precisely and conveniently the beginning of erosion (critical shear stress) of clay samples and to permit sample condition to be easily controlled. Consequently, the resistance to water erosion of clay samples could be compared.

An investigation was made of the difference in water erosion resistance between two clay systems (bentonite, a type of montmorillonite clay mineral, and kaolin clay, a kaolinite clay mineral) at different water contents by considering the fundamental properties of each clay mineral.

Erosion resistance of both bentonite and kaolin clay at different water temperatures was studied.

Some mathematical models were employed to calculate the interparticle forces between clay particles and to examine the effects of concentration, valence of cations in the bulk solution of a clay system, and temperature of pore water of the clay systems of these interparticle forces.

Various physical parameters for each clay sample were also collected and an attempt was made to relate them to erosion resistance.

LO, R. T. Y., and WEBER, W. J., JR. 1984 (Feb). "Flocculent Settling in Quiescent Systems," Journal of Environmental Engineering, Vol 110, No. 1, pp 174-189.

The development of an empirical equation for description of the distribution of flocculent solids in quiescent settling columns is described. The equation is predicated on observations made in the course of concentration-depth-time analyses of settling data for flocculent and nonflocculent solids in quiescent and agitated settling columns. The validity of the equation is verified by its application to ten different quiescent flocculent settling studies involving several sewages and natural lake and river suspensions.

LORING, D. H. 1976 (Jul). "The Distribution and Partition of Zinc, Copper, and Lead in the Sediments of the Saguenay Fjord," Canadian Journal of Earth Sciences, Vol 13, No. 7, pp 960-971.

Zinc (Zn) concentrations vary between 43 and 145 ppm, copper (Cu) concentrations between 6 and 33 ppm, and lead (Pb) concentrations between 14 and 66 ppm in relation to sediment texture and location in the Saguenay fjord. The concentrations of the elements increase with decreasing grain size; the highest concentrations occur in the fine-grained sediments (muds) in the upper part of the fjord and they decrease downstream. On the average, the fjord muds are enriched in Zn and Pb when compared to sediments from the St. Lawrence estuary and the open Gulf of St. Lawrence.

Acetic acid extractions of the sediments indicate that 14 to 29 percent of the total Zn, 14 to 21 percent of the total Cu, and 12 to 25 percent of the total Pb are contributed by the nondetrital (acid soluble) fraction, and the remainder (70-88 percent) is contributed by the detrital (acid insoluble) fraction. Most of the Zn, Cu, and Pb in the detrital fraction are held in discrete sulphide minerals. These minerals accumulate at the same rate as other detrital sedimentary material in response to the present depositional conditions. Nondetrital Zn, Cu, and Pb contributions represent the portion of the total element content adsorbed by fine-grained inorganic and organic material during transport and deposition. The distributions of nondetrital Pb and to a lesser extent of Zn and Cu in the fjord are apparently controlled by the downstream dispersal from local industrial sources of mercury (Hg)-rich terrestrial organic matter.

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MacARTHUR, R. C. 1979. "Turbulent Mixing Processes in Partially Mixed Estuaries," Ph.D. Dissertation, University of California, Davis, Calif.

Analyses of observed half-hourly data collected from the Savannah River estuary have provided a better understanding of several of the complex mixing processes occurring in partially mixed estuaries. A method of estimating the nature and magnitude of the parameters which describes the flow, in the region near the bed, located below the maximum density gradient in partially mixed estuaries is developed and validated. Accurate determination of these parameters allows the calculation of the vertical profiles of velocity and an estimation of the vertical turbulent mixing coefficients within this region. Calculated values of the local bed shear stress obtained from numerically integrating a form of the two-dimensional momentum equation were found to be accurate when compared to the measured sediment bed shear strengths for various orders of aggregation throughout a mean tide.

Orderly flows occur during specific periods of time during a tidal cycle and only within certain vertical regions of the flow within the Savannah estuary. Criteria are developed to be able to identify these periods of "fully developed" flow. Vertical distributions of velocity, shearing stress, and turbulent exchange coefficients are derived from Prandtl and von Karman forms of the "mixing length theory." These relations are applied and validated with observed data from the Savannah estuary. Two distinct regions of flow separated by a central mixing zone are identified and analyzed for their individual hydrodynamic properties. Couette flow characteristics and those properties typically found in "drag-reducing" flows are identified and analyzed within the "near-bed" region.

A simple linear relationship is found to exist between the near-bed layer turbulent Schmidt number and Reynolds number. This relationship confirms results obtained from dimensional analyses and compares closely with previous results observed in laboratory flumes by Orlob. Observation of logarithmic velocity profiles, constant shearing stress distributions, and simple linear Schmidt-to-Reynolds number relationships within the near-bed region indicates that boundary-layer type flows exist during periods of fully developed flow in partially mixed estuaries. Results from the analyses reported herein indicate that the presence of stable density gradients and high concentrations of suspended sediment require the modification of fundamental turbulent flow relationships in order that observed local flow characteristics be accurately described.

McCANN, S. B., REINSON, G. E., and ARMON, [illegible]. 1977 (Nov). "Tidal Inlets of the Southern Gulf of the St. Lawrence, Canada," Coastal Sediments '77, American Society of Civil Engineers, pp 504-519, Charleston, SC.

Barrier islands and sandpits, cut by numerous tidal inlets, are an important element of the coastline of the southern Gulf of St. Lawrence which had been little studied prior to 1970. However, recent investigations by the authors and others have provided a basic understanding of the morphology and dynamics of the barrier systems and some of the principal inlets. Only one of the inlets, Portage Channel at the entrance to the Miramichi estuary, is utilized by ocean-going vessels, to reach the New Brunswick ports of Chatham and Newcastle, but there are numerous small craft harbors situated inside the barriers all around the southern gulf. Thus, many of the inlets are heavily utilized by small fishing vessels, and periodic dredging of inlet and lagoon channels is necessary. The present paper examines shoreline and inlet conditions along the NE coast of New Brunswick, in particular at the entrance to the Miramichi estuary, and along the Malpeque shore of Prince Edward Island. The two areas illustrate the range of conditions in terms of littoral drift rates, inlet size and stability, and associated sand bodies which are typical of the region.

E, I. N. 1984. "Size Spectra and Aggregation of Suspended Particles in 'eep Ocean," Deep-Sea Research, Vol 31, No. 4, pp 329-352.

Work of the last 10 years has demonstrated that oceanic particle size 'ibution by volume tends to be flat at midwater depths (equivalent to a .ative particle number distribution with a slope of -3) and is peaked in :loid layers with active resuspension and in surface waters with active 'gical production. The observed loss of fine peaks from the suspensions .eld flat distributions requires aggregation of the material, as the fines .e slowly. Mechanisms leading to particle collision are examined; for 'actions between particles of similar size, Brownian motion dominates be- ..5 to 8 μm. However, if large particles (such as 'marine snow') are 'nt at realistic concentrations, they become important in the removal of particles by shear controlled coagulation. The coagulation times calcu- l for shear are too long for steady state to be presumed while the size :ibutions evolve under the influence of coagulation mechanisms. Therefore 'stions that the flat size distributions are quasi-stationary results of :-controlled coagulation are rejected, and the notion that there is sub- l production of particles at different points in the spectrum is favored. production and the subsequent scavenging of small particles by large set- ; ones confers great importance on components of biological origin in both lding elements of the total size spectrum and determining the distribution sedimentation of others of lithogenic origin. In surface waters, filtra- rates by zooplankton indicate that aggregation rates of particles above icron sizes are biologically determined.

AD-A188 349 FINE-GRAINED SEDIMENTS; AN ANNOTATED BIBLIOGRAPHY ON THEIR DYNAMIC BEHAVI..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 4/6

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McCAVE, I. N. 1979. "Suspended Sediment," Estuarine Hydrography and Sedimentation, K. R. Dyer, ed., Chapter 6, pp 131-185, Cambridge University Press, Cambridge, England.

To the casual observer, suspended material is one of the most obvious features of estuaries. They tend to be muddy--muddier than the rivers flowing into them or the sea beyond. In fact, most estuarine circulation systems lead to the entrapment of suspended sediment, making the study of this material of prime importance as aspects of both estuarine behavior and pollutant dynamics. The location of many industries along the banks of estuaries makes the latter aspect very pressing. This chapter deals with the determination of suspended material concentration, properties, and interpretation of results. The terms suspended material, suspended sediment, suspended matter, suspensate (USA), and Seston (German usage) all refer to total solids held in suspension in water, though operationally what is retained on a filter is determined. These terms will be used as synonymous and interchangeable.

McCAVE, I. N. 1975. "Vertical Flux of Particles in the Ocean," Deep Sea Research, Vol 22, pp 491-502.

Although most material both on the sea bed and in suspension is very fine, evidence suggests that most material reaching the bottom does so rapidly in aggregates. Sizes of suspended material below 200 to 400 m in the oceans follow a hyperbolic distribution with slopes between -2.4 and -3.6. Volume distributions are calculated and converted to mass distributions using an assumed density distribution. Stokes velocities are calculated for particle size classes. Most of the particle flux, the product of settling velocity and mass, is in the coarser size classes. Assumption of steady state requires aggregation of small particles in the upper layers of the ocean to maintain the concentrations of the larger rapidly sinking particles. Current sampling procedures may miss much of the material in rapid vertical transit.

McDOWELL, D. M., and O'CONNOR, B. A. 1982. "Numerical Analysis of Sediment Transport in Coastal Engineering Problems," Hydraulic Modelling in Maritime Engineering, pp 79-94, Thomas Telford Ltd, London, England.

The paper describes the present state of the art of numerical modeling of coastal sediment transport problems and how current research is endeavoring to improve it. The paper shows that all present day numerical models contain approximations. Many models were found to adopt a multistage approach whereby waves, tides, and wind-induced flows were modeled over a large area on a coarse network of computation points remote from the area of interest, while the effects of wave breaking and reflection as well as tides and wave-induced currents were modeled over a smaller local area on a more densely packed network. If structures of complex topography were present in a local area, then wave diffraction effects were also included, although few models were found which could cope with the inclusion of all factors.

It is shown that the translation of environmental forces into sediment movement was usually accomplished using either a force-balance approach, whereby sediment transport rates at a point were related to applied shear stress, or an energy approach in which sediment movement by both bed and suspended load were related to the energy contained in a particular wave or current system. The energy approach was used originally to model littoral transport on beaches where tidal effects were small in comparison with wave effects. More recent models, particularly of combined tide and wave problems, were found to use the force-balance approach to calculate bed-load movements and then a turbulent mixing theory to calculate the amount of sediment moving in suspension.

Current research was shown to be directed along three main routes. Theoretical work was in progress on wave-current interactions, on the 3-D modeling of near-shore currents, and on the hydrodynamics of flows over bed forms. Laboratory work was in progress on wave-current interactions and wave run-up and on the hydrodynamics of wave, current, and combined wave/current flows. Field work is in progress on the initiation of sediment movement, on bed-form movement, and on the distribution of currents and suspended solids in wave/current flows.

McDOWELL, D. M., and O'CONNOR, B. A. 1977a. "Sediment Movements," Hydraulic Behaviour of Estuaries, Chapter 4, pp 83-123, John Wiley and Sons, New York.

Many of the world's major cities have grown to their present size because they are centered around a large navigable tidal river or estuary. Failure to preserve adequate navigation channels has often caused a city to decline in importance or even be abandoned altogether. Engineering schemes concerned with tidal rivers and estuaries must therefore be carefully investigated in order to avoid disastrous changes in the size and location of port approach channels.

This paper is an attempt to make the reader aware of the possible sources and types of sediment which contribute to tidal shoaling problems, as well as the various sediment transport processes at work in a tidal environment and the factors on which they depend.

McDOWELL, D. M., and O'CONNOR, B. A. 1977b. "The Study of Tidal Systems: Field Measurements," Hydraulic Behaviour of Estuaries, Chapter 5, pp 124-145, John Wiley and Sons, New York.

Estuaries have been shown to be regions in which many factors interact. Disturbance of any of them can affect others. The behavior of a system makes comprehensive study difficult. Prediction of future behavior can only be made by use of some kind of simulator, such as mathematical equations, analogue, or digital representation, or by physical modeling of an estuary. In each case, field measurements are needed to provide boundary conditions and data for calibration. Programs of field measurements must be planned to suit the requirements of each new situation.

McDOWELL, D. M., and O'CONNOR, B. A. 1977c. "The Study of Tidal Systems: Hydraulic Models," Hydraulic Behaviour of Estuaries, Chapter 8, John Wiley and Sons, New York.

The laws of scaling of hydraulic models can be determined either by dimensional analysis as described in many textbooks on hydromechanics or from the equations of motion. In this chapter, the equations of motion have the advantage over dimensional analysis that they give a physical insight into the processes that must be reproduced. They can also be used to determine the order of magnitude of the variables in such a way that their significance can be established and the consequences of their omission assessed.

McDOWELL, D. M., and O'CONNOR, B. A. 1977d. "Control of Estuaries," Hydraulic Behaviour of Estuaries, Chapter 9, pp 225-249, John Wiley and Sons, New York.

The management of an estuary is a subtle process. It consists of first understanding and then guiding the forces of nature, but natural forces cannot be predicted in detail and the consequences of guiding them can only be forecast in broad terms. Management is a continuing process of guidance of the system, observing its response and adjusting the guidance as required. Careful observation of the system and use of the minimum effort to achieve a goal are the principles to be followed; to these might be added the avoidance of permanent works unless they are absolutely necessary.

The management of estuaries will continue to be an art, but the scientific principles outlined in this book, coupled with experience of the behavior of various systems, should prevent ignorance of the major consequences of engineering works. In the final analysis, experience of other systems provides the best indication of things that could go wrong as a result of management decisions.

McGREGOR, R. C. 1974. "The Influence of Channel Shape on Shoaling in Tidal Estuaries," The Geophysical Journal of the Royal Astronomical Society, Vol 36, pp 599-606.

The nonperiodic equations which govern tidal flow in estuaries are solved for a channel of arbitrary cross section. The solution, which relates all the principal parameters associated with estuarial flow to the location of the zeros, shows that with data appropriate to the River Humber the self-flushing effect of deep channels can cause the shoaling point to vary some 11 km at different points across the estuary. The prediction of the lateral location of the sedimentation is very good.

McGREGOR, R. C. 1971 (Dec). "The Influence of Topography and Pressure Gradients on Shoaling in a Tidal Estuary," The Geophysical Journal of the Royal Astronomical Society, Vol 25, No. 5, pp 469-480.

The nonperiodic equations governing tidal motion in estuaries are developed. These equations, which determine the density-driven currents within the estuary are then demonstrated to be easily soluble for estuaries of arbitrary topography, river flow, and density distribution. The solution relates all the principal parameters associated with estuarial flow to the location of the deposition zone and can also be used to demonstrate the importance of different agencies in particular estuaries. The evaluation of the solution is very economical on computing time and requires only readily available data. Results are discussed with respect to data appropriate to the River Thames and the River Humber and agreement with observation is very good.

McLAUGHLIN, R. T., JR. 1959 (Dec). "The Settling Properties of Suspensions," Journal, Hydraulics Division, American Soc-ety of Civil Engineers, Vol 85, No. HY12, pp 9-41.

This paper contains the results of an analytical and experimental investigation of the settling properties of suspensions of particles in fluid. The use of these properties in predicting the sedimentation of the particles is outlined.

MADSEN, O. S., and GRANT, W. D. 1976 (Jan). "Sediment Transport in the Coastal Environment," Report No. 209, Massachusetts Institute of Technology, School of Engineering, Cambridge, Mass.

The subject of sediment transport in the coastal zone is investigated and the answers to some of the basic questions of sediment transport in unsteady, oscillatory flow are presented.

By adopting Jonsson's results for the bottom shear stress associated with a simple wave motion, it is shown that Shields' criterion of the initiation of sediment movement on a flat bed holds in unsteady as well as steady flow. A simplified analysis as well as experimental data show the side effects associated with the experimental procedure in which a tray containing sediment is oscillated in still water are generally insignificant, and is therefore a valid procedure for studying certain aspects of wave sediment interaction. Also, Shields' parameter is identified as the physically important parameter quantifying the fluid-sediment interaction.

The general application of the derived sediment transport relationship for predicting net rates of sediment transport in the presence of second order effects such as bottom slope, wave asymmetry, mass transport currents, and coastal currents is discussed. This discussion serves also to identify needed areas for future research. It is concluded that only the case of a small amplitude wave and a steady current seems to be understood to the extent that it is reasonable to evaluate the resulting sediment transport with any degree of confidence. Fortunately, this is a rather important situation in most offshore regions.

MANHEIM, F. T. 1970. "The Diffusion of Ions in Unconsolidated Sediments," Earth and Planetary Science Letters, Vol 9, pp 307-309.

Diffusion in unconsolidated sediments generally proceeds at rates ranging from half to one twentieth of those applying to diffusion of ions and molecules in free solution. Diffusion rates are predictable with respect to porosity and path tortuosity in host sediments, and can be conveniently measured by determinations of electrical resistivity on bulk sediment samples. Net ion flux is further influenced by reactions of diffusing species with enclosing sediments, but such influences should not be confused with or lumped with diffusion processes.

MANHEIM, F. T., HATHAWAY, J. C., and UCHUPI, E. 1972 (Jan). "Suspended Matter in Surface Waters of the Northern Gulf of Mexico," Limnology and Oceanography, Vol 17, No. 1, pp 17-27.

Analyses of about 200 surface water samples collected during late fall 1966 show that concentrations of suspended matter greater than 1 mg/ℓ were restricted to within a few kilometers off Florida, but extended more than 100 km off Louisiana and Texas. Suspensates from areas farther than 100 km from shore contained mainly combustible organic matter, part of which was attributable to living plankton.

Organic aggregates encompassing appreciable amounts of inorganic detritus were particularly noteworthy in transitional areas. Zooplankton metabolism and fecal pellet production appears to be a geologically significant mechanism for depositing fine suspended matter and may contribute to the zonation of bottom sediments.

The mineral composition of surface suspensates ranges from a low magnesian calcitearagonite suite off Florida to montmorillonite-kaolinite combinations from Alabama to Texas. The mineral composition of the suspensates resembles that of the bottom sediments in each area.

MANTZ, P. A. 1980 (Jul). "Low Sediment Transport Rates Over Flat Beds," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 106, No. HY7, pp 1173-1190.

In order to demonstrate the effect of stability on flat bed transport, this study quantifies the erosion of sediment beds prepared at different stabilities. In nature, the latter can occur when sediments are deposited during different flow conditions. The experiments simulate this process, and additionally examine the influence of solid shape on transport by choosing lightweight discs as the sediment. It was found for these two-dimensional solids that bed stability was as important a variable upon flat bed transport as solid size and fluid temperature, for the range of turbulent water flows tested.

MARSHALL, N. F. 1978. "Large Storm-Induced Sediment Slump Reopens an Unknown Scripps Submarine Canyon Tributary," Sedimentation in Submarine Canyons, Fans, and Trenches, D. J. Stanley and G. Kelling, eds., Chapter 7, pp 73-84, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

The occurrence of a marine slump near Scripps Institution of Oceanography and the fortuitous discovery of that slump have provided the opportunity to develop concepts pertaining to the initiation of such slumps and their significance in the dynamic process of sediment transport to the deeper sea floor and to describe their particular morphology as it applies to the marine environment. Differential wave pressure, caused by large storm waves, is suggested as a mechanism for the initiation and headward advance of shallow water slumps on slopes of relatively low gradient.

MATSUMOTO, K., and MORI, Y. 1975 (Apr). "Settling Velocity of Floc--New Measurement Method of Floc Density," Journal of Chemical Engineering of Japan, Vol 8, No. 2, pp 143-147.

Buoyant density of floc can be obtained by simultaneous use of Odén balance method and photoextinction method, provided that the relationship between size and settling velocity of floc is known and that flocculation and redispersion of flocs do not occur significantly during settling. By use of this method, the results presented in this paper are obtained. Settling velocity of activated sludge and floc formed by bentonite and alum can be represented by a settling velocity equation for solid spheres.

MATSUMOTO, K., and SAQANUMA, A. 1977. "Settling Velocity of a Permeable Model Floc," Chemical Engineering Science, Vol 32, No. 4, pp 445-447.

In this paper, the effect of permeability on the settling velocity of a porous sphere was experimentally investigated by using a permeable model floc made of steel wool, which satisfied the assumptions contained in their theories. The results obtained in experiments were also compared with their theories.

The results obtained will be applicable to calculating the settling velocity of a floc composed of filamentous or chain-like materials, such as activated sludge which cause bulking and other filamentous microorganisms if the permeability of the floc can be known.

MAYOR-MORA, R., MORTENSEN, P., and FREDSOE, J. 1976 (Jul). "Sedimentation Studies on the Niger River Delta," Proceedings, Fifteenth Coastal Engineering Conference, American Society of Civil Engineers, pp 2151-2169.

An area of the Niger River delta was studied from October 1974 to October 1975 in connection with feasibility studies and preliminary design for the development of a deep draught port in the western portion of the delta. The provision of a 100-km, 8- or 10-m navigation channel through one of the entrances from the sea, up to new port facilities at Warri, required comprehensive hydraulic, hydrographic, and sedimentation surveys over the period.

The sedimentation studies dealt primarily with the conditions at the entrances. The main entrance to the existing ports of the western Niger delta used today by ships of up to 6 m draught is the partly protected entrance of Escravos. At this entrance, two moles were constructed around 1960 following intensive hydraulic studies that included testing on physical models.

However, the sedimentation is concluded to be in the order of 2 million cubic meters per year in the lee of the breakwaters. This sedimentation has been explained and possible solutions discussed.

An unprotected channel through the Forcados Entrance was considered as an alternative to improvement of the Escravos Entrance. Such a channel would be dredged through sand, and the sedimentation due to combined current and wave actions was studied.

A theory for sedimentation of suspended load in an unprotected dredged channel in non-cohesive material was developed in connection with the study of Forcados Entrance. This theory is presented as an appendix.

MEADE, R. H. 1969 (Mar). "Landward Transport of Bottom Sediments in Estuaries of the Atlantic Coastal Plain," Journal of Sedimentary Petrology, Vol 39, No. 1, pp 222-234.

The estuaries of the Atlantic Coastal Plain, which are the mouths of rivers drowned during the latest eustatic rise in sea level, are being filled with sediment. River-borne sediment is partially trapped in the estuaries by the predominantly landward flow of estuarine bottom waters. The main evidence of this are measurements of the sediment flux (suspended-sediment concentration and water velocity measured at intervals of depth and through tidal cycles) that show sediment being moved progressively landward along the bottom. Comparisons of the loci of sediment deposition and the patterns of water circulation show that sediment accumulates in estuaries near the upstream limit of landward bottom flow.

The movement of sands into the mouths of the larger estuaries from the continental shelf and nearby beaches is also suggested by several other lines of evidence. Bottom waters of the continental shelf move progressively into the mouths of estuaries, and they presumably carry bottom sediments with them. Beach sands move toward and into the mouths of some estuaries at rates of several hundred thousand cubic metres per year. And distinctive mineral components in the lower reaches of estuaries suggest that the bottom sediments were derived from offshore.

The rates of filling of the estuaries have been different in the northern and southern parts of the Coastal Plain. The large northern rivers carry disproportionately small loads of sediment that have not yet filled the deep valleys which were cut during the ice ages. The southern rivers carry larger sediment loads relative to the sizes of their valleys, and consequently their estuaries are mostly filled with sediment.

MEADE, R. H. 1973. "Net Transport of Sediment Through the Mouths of Estuaries: Landward or Seaward?" Proceedings, International Symposium on Interrelationships of Estuarine and Continental Shelf Sedimentation, pp 207-210.

The drowned river valleys and other semi-enclosed embayments on the middle Atlantic coast of the United States between Cape Cod and Cape Lookout constitute one of the world's largest and best studied assemblages of estuaries. Natural sources of modern sediments in these estuaries and of the sediments on the wide continental shelf that adjoins them are (a) rivers, (b) shorelines (those in the estuaries as well as those facing the open sea), and (c) older bottom sediments on the shelf.

Do the rivers and estuaries supply more sediment to the shelf than the shelf supplies to the estuaries? Evidences for transport of sediment onto the shelf from estuaries are: (a) net seaward drift of surface waters in estuaries and across the shelf, (b) plumes of turbid water that emerge from estuaries onto the shelf, and (c) measurements that suggest a net seaward transport of sediment through the mouth of Delaware Bay. Evidences of transport of shelf sediment into estuaries are: (a) net landward drift of bottom waters on the inner half of the shelf and in the estuaries, along with net longshore drift toward the mouths of the estuaries, (b) accumulation of fine sediment in estuaries in contrast with the prevalence of coarse relict material on the shelf, and (c) mineral compositions of estuarine sediments (and suspended sediment in shelf waters) that correspond more closely to older shelf sediments than to sediments being carried by inflowing rivers. Although the conclusion is by no means certain, the evidence that is presently available gives more support to a net landward movement of sediment from the shelf into the estuaries.

MEADE, R. H. 1968. "Relations Between Suspended Matter and Salinity in Estuaries of the Atlantic Seaboard, U.S.A.," International Association Science Hydrology, Vol 4, pp 96-108.

Despite the suggestion by laboratory experiments that suspended matter in rivers is flocculated and deposited where it reaches salt water, the concentrations of suspended matter in estuaries associated with some moderately large rivers of the Atlantic seaboard show no accelerated decrease that can be attributed to salt flocculation. Velocities of the estuarine waters are apparently sufficient to obscure the expected effects of salinity and keep the material in suspension. The general decrease in suspended matter associated with increasing salinity in the seaward direction can be attributed to the simple dilution of river suspensions by sea water.

Superimposed on the general seaward decrease in suspended concentration is a maximum concentration near the upstream limit of sea salt. Suspended concentrations decrease both upstream and downstream of the maximum. This maximum has been found at one time or another in all the estuaries that have been sufficiently studied. It seems to reflect the accumulation of suspended matter near the salt limit by net landward flow along the estuary bottom.

MEADE, R. H. 1976 (Jun). "Sediment Problems in the Savannah River Basin," Reprinted from The Future of the Savannah River, B. L. Dillman and J. M. Stepp, eds., pp 105-129, Denver, Colo.

Sediment in the Savannah River is derived mainly from the parts of the basin that lie above the fall line--particularly the Piedmont province. Accelerated erosion has stripped some 3 to 4 billion cubic meters of sediment from the Piedmont uplands since 1700. However, more than 90 percent of this sediment has not been carried across the fall line by the river; it remains stored on the hill slopes and in the stream bottoms of the Piedmont. Large reservoirs trap most of the sediment moving down the main stem of the Savannah. The sediment that accumulates in the dredged navigation channels of the estuary is only partly attributable to upland sources; other sources remain to be identified.

MEADE, R. H. 1972a. "Sources and Sinks of Suspended Matter on Continental Shelves," Shelf Sediment Transport: Process and Pattern, D. J. P. Swift, D. B. Duane, and O. H. Pilkey, eds., Chapter 11, pp 249-262, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

While river sediments are the principal sources of suspended matter on many continental shelves, their importance on the Atlantic Continental Shelf of the United States is less than that of biogenic detritus produced by shelf organisms and of material resuspended from the shelf bottom. The major sites of accumulation of suspended matter from the Atlantic shelf are in the large estuaries and coastal marshlands rather than on the shelf itself or in the deep sea. Sources other than river sediments and sinks other than the sea floor should be given ample consideration in assessing the dispersal of suspended sediments on other continental margins of the world.

MEADE, R. H. 1972b. "Transport and Deposition of Sediments in Estuaries," The Geological Society of America, Inc., Memoir 133, pp 91-120.

The dynamic processes involved in the circulation of estuarine waters are probably the most important influences on the transport and deposition of sediments in estuaries. In moderately stratified or vertically homogeneous estuaries such as the Savannah (Georgia) and Thames (England) Rivers, sediments are moved progressively landward along the bottom and they accumulate near the limit of net landward flow. In highly stratified estuaries such as Southwest Pass of the Mississippi River, coarse sediments are trapped near the toe of the salt wedge while fine sediments are carried seaward over the salt wedge with the outflowing river water. On the basis of present information, however, we cannot always distinguish between the results of natural dynamic processes and the results that are induced by the activities of man.

Other possible influences on estuarine sedimentation are the inorganic and organic processes that tend to aggregate sedimentary particles and the properties of the particles themselves. The effects of salt flocculation have been amply demonstrated by laboratory experiments, but no field evidence is available to show their importance in complex natural estuaries. The agglomeration of sediments by organisms likewise has been investigated in the laboratory, but its importance in nature needs to be evaluated. Our knowledge of the composition and size distribution of the sediment particles contributed to estuaries from different sources is seriously deficient.

MEHTA, A. J. 1983a (Aug). "Characterization Tests for Cohesive Sediments," Proceedings of Frontiers of Hydraulic Engineering Conference, American Society of Civil Engineers, pp 79-84, Cambridge, Mass.

Estuarial fine, cohesive sediments require special characterization tests for the purpose of evaluating fluid-sediment properties and appropriate transport modeling parameters. Some important parameters have been identified. These parameters should be determined from a combination of requisite laboratory and field experiments. Such a combination results in the evaluation of the parameters, such as those characterizing erosion and deposition, with a degree of confidence. Furthermore, laboratory scale effects, when present, are identified in this way. Necessary experimental procedures have been reported in the literature and can be utilized provided some specialized equipment is available.

MEHTA, A. J. 1983b (Mar). "Fine Sedimentation in Estuaries and Harbors, Part I. Fine Sediment Transport," Notes from Short Course on Port Engineering, University of Florida, Gainesville, Fla.

Fine, cohesive sediments in estuaries are comprised largely of clay-sized particles plus fine silts. The remainder may include biogenic detritus, algae, organic matter, waste materials, and sometimes small quantities of very fine sand. According to the generally accepted classification in engineering practice, particles of size between 0.060 mm and 0.002 mm (60 microns to 2 microns) are considered to be silts while clays are less than 0.002 mm (2 microns) in size. Although in water with a very low salinity (less than about 1 part per thousand) the elementary sediment particles are usually found in a dispersed or "non-salt flocculated" state, small amounts of salts (1 to 3 parts per thousand) are sufficient to repress the electrochemical surface repulsive forces between the elementary particles, with the result that the particles coagulate to form much larger units known as aggregates. Each aggregate may contain thousands or even millions of elementary particles and have a settling velocity that is much larger than those of the elementary particles. The transport properties of the aggregates are affected by the hydrodynamic conditions and by the chemical composition of the suspending fluid. Most estuaries contain abundant quantities of cohesive sediments which usually occur in the coagulated form in various degrees of aggregation. Therefore, an understanding of the transport properties of these sediments in estuaries requires a knowledge of the manner in which the aggregates are transported in these waters.

MEHTA, A. J. 1983c (Mar). "Fine Sedimentation in Estuaries and Harbors, Part II. Sedimentary Processes," Notes from Short Course on Port Engineering, University of Florida, Gainesville, Fla.

A binary fluid-sediment mixture can be considered to exist in four states in the estuarial mixing zone: a suspension in horizontal transport; a stationary suspension which may possess a vertical velocity component; a consolidating deposit; or a settled, consolidated bed. A stationary suspension with practically no mechanical strength results from settling of aggregates in transport, particularly at times close to slack water. Under suitable conditions, a bed deposit with a skeletal soil framework develops. Such a deposit tends to exhibit a non-Newtonian behavior with a small but measurable cohesive shear strength. Consolidation of this deposit due to overburden and thixotropic rearrangement results in a settled bed with a lower water content, a higher shear strength, and a more stable structural configuration.

Erosion of a stationary suspension, which typically could occur shortly after current reversal following slack water, has been referred to as redispersion. Erosion of a consolidating or a recently settled bed is referred to as resuspension. Resuspension of even a few centimeters of the flow-deposited surficial layer of a bed can contribute measurably to the suspended load. For example, assuming a bed density of 0.336 g/cm^3, resuspension of 8-cm-thick bed in a 5-m-deep estuarial water column will result in a suspended sediment concentration of 5.4 g/ℓ, which is a significant amount.

The size, the density, and the shear strength of the sedimentary unit in suspension in a given estuarial environment is controlled by the processes of coagulation and aggregation. These in turn influence sediment deposition and erosion which are the two principal processes that determine the rates of transport, shoaling, and scour.

MEHTA, A. J. 1983d (Mar). "Fine Sedimentation in Estuaries and Harbors, Part III. Shoaling in Harbors," Notes from Short Course on Port Engineering, University of Florida, Gainesville, Fla.

The low flow velocities prevalent in estuaries, harbors, and waterways cause deposition of suspended fine sediments that enter these systems with tides, currents, local drainage, and as a result of diffusion from the flows outside entrances. Shoaling results in reduced navigability and berthing facility for vessels. Shoaling due to fine sediment deposition is a major problem, for example, at numerous commercial and recreational harbors in the United States and elsewhere.

The ability to predict the rate of shoaling at the design stage is, of course, of greatest value. Nevertheless, monitoring the rate of shoaling in an existing project has its benefits. Due to the wide variations in density of fine sediment deposits, it is essential that records be maintained on the basis of dry weight of the sediment and not volume as is the common practice. Accurate dredging records that include volume and density of material removed provide an estimate of the rate of shoaling in a system that has achieved equilibrium. Repeated hydrographic surveys and profiling of the bed for the density enable the calculation of the mass of material deposited between surveys. Together, dredging records and bottom surveys including density profiles permit the estimation of the rate of shoaling. Sources of shoaled sediment have been determined by the study of mineralogy, associated organic compounds, and other chemicals sorbed on the sediments.

Prediction of the rate of shoaling can be accomplished by evaluation of each of the parameters by simple calculations or by mathematical modeling of the flows and sediment transport in more complex situations. Where the harbor is large and a real distribution of shoals is desired, mathematical modeling is the only option.

MEHTA, A. J. 1981. "Review of Erosion Function for Cohesive Sediment Beds," Proceedings, First Indian Conference on Ocean Engineering, pp I-122 - I-130, Indian Institute of Technology, Madras, India.

Resuspension of fine, cohesive, sedimentary bed material is generally caused by the action of erosive hydrodynamic forces characterized by the bed shear stress. Mathematical models for the prediction of fine sediment transport require a relationship between the rate of erosion and the time-mean bed shear stress τ, as a bottom boundary condition for the upward flux of sediment. A review of laboratory investigations reveals a variety of test conditions, some of which have been described inadequately. It is however noted that in the case of surface erosion of bed material under steady, turbulent flows, the $\varepsilon-\tau$ relationship derived from various investigations is described by a four-parameter, dimensionless equation. A special case of this equation is a two parameter relationship which has been mentioned in the literature previously. Resuspension under wind-generated waves is a more complex phenomenon in which it is revealed that there can be a substantial degree of interaction between the dynamics of the wave and the bed itself. In all instances, it is noted that the physico-chemical properties of the sediment-fluid system and the stress history of the bed prior to resuspension have a strong influence on the rate of erosion.

MEHTA, A. J., and HAYTER, E. J. 1981 (Dec). "Preliminary Investigation of Fine Sediment Dynamics in Cumbarjua Canal, Goa, India," UFL/COEL-81-012, Coastal and Oceanographic Engineering Department, University of Florida, Gainesville, Fla.

Sediment management in estuaries requires an understanding of fine, cohesive sediment transport processes which typically characterize the estuarine regime. A preliminary field investigation was carried out in Cumbarjua Canal, Goa, India, where the sediment is almost entirely in the fine range and the flows are primarily tide induced. In a 10.4-km reach of the canal, data on currents, tides, sediments, and wind were obtained. The hydrodynamic and the sedimentary regimes of the canal under fair weather conditions are distinct from the regimes in monsoon. In fair weather, the flow is vertically mixed with a small longitudinal salinity gradient. Under the typically moderate tides, the suspended sediment concentrations are low, the shearing rates in the flow are low to moderate, and aggregation of the flocculated kaolinitic sediment occurs, but the order of aggregation is low, and small diameter aggregates with low settling velocities are formed in suspension. Consequently, the waters do not clarify at slack. Wind-induced waves appear to play a role in contributing to the suspended sediment load. The overall sediment balance is determined by the cumulative contributions to the transport during fair weather and during monsoon. The canal appears to be well suited for further work in elucidating the mechanisms characterizing suspended cohesive sediment transport in tidal waterways.

MEHTA, A. J., and PARTHENIADES, E. 1975. "An Investigation of the Depositional Properties of Flocculated Fine Sediments," Journal of Hydraulic Research, Vol 13, No. 4, pp 361-381.

It is shown that the process of deposition of the flocs appears to be controlled by the stochastic turbulent processes in the zone near the bed. There, the strongest shear and lift forces prevail, and these in turn control the size and shear strength distributions of the flocs in suspension. Thus a floc which is strong enough to withstand the maximum shearing force acting on it near the bed will settle on the bed and will attach itself to the bed by cohesive bonds. On the other hand, a floc with a relatively low shear strength will be broken into two or more smaller units and these will be re-entrained in the suspension by the strong hydrodynamic lift forces. This hypothesis in fact implies that the steady-state suspension represented by C_{eq} contains flocs that are too weak and small to be able to withstand the shear stresses near the bed and deposit. The segregation of weak flow from strong ones near the surface of the bed by a stochastic selection process implies that the flocs possess an apparent settling velocity, W_s, of deposition. It can be shown through a simple finite volume sediment continuity principle that W_s is an exponentially decreasing function of time, and therefore cannot be considered to be a constant.

MEHTA, A. J., and PARTHENIADES, E. 1973a (Mar). "Depositional Behavior of Cohesive Sediments," Technical Report No. 16, University of Florida, Coastal and Oceanographic Engineering Laboratory, Gainesville, Fla.

The depositional properties of flocculated fine cohesive sediments in a turbulent flow field have been investigated. The experiments have been conducted in a special apparatus consisting of a system of an annular channel containing the sediment suspension, and an annular ring positioned within the channel, and in contact with the water surface. A simultaneous rotation of the two components in opposite directions and at properly selected speeds eliminates the secondary currents and generates a uniform turbulent flow field free from any floc-disrupting elements.

For a given suspension and flow condition, the time-concentration relationship indicates an initial period of deposition, after which the suspended sediment concentration reaches a steady state value, C_{eq}, defined as equilibrium concentration. It is found that the ratio $C^*_{eq} = C_{eq}/C_o$, where C_o is the suspended sediment concentration at the beginning of deposition, varies solely with the bed shear stress, τ_b. This variation of C^*_{eq} with τ_b, and consequently of $C^{**}_{eq} = 1 - C^*_{eq}$ defined as the degree of deposition, is according to a logarithmic-normal law. It is further found that the degree of deposition, for any given suspension, is characterized by the minimum bed shear stress, τ_{bmin}, below which C^*_{eq} is zero, i.e., below which the entire amount of initially suspended sediment eventually deposits. Finally, it is shown that when the ambient water quality is constant, the cation exchange capacity of the sediment, which is representative of the physico-chemical properties of the sediment, correlates with τ_{bmin}, and therefore ultimately characterizes the degree of deposition.

MEHTA, A. J., and PARTHENIADES, E. 1973b. "Effect of Physico-Chemical Properties of Fine Suspended Sediment on the Degree of Deposition," International Association for Hydraulic Research, International Symposium on River Mechanics, Vol 1, pp 465-475.

Experimental measurements have shown that a given flow can maintain in suspension a constant fraction of a suspended cohesive sediment. In a closed, self-contained flow system, this fraction is represented by the ratio $C^*_{eq} = C_{eq}/C_o$, where C_o is the suspended sediment concentration at the beginning of deposition, and C_{eq} is the final steady-state concentration. It is found that the ratio $1-C^*_{eq}$, referred to as the degree of deposition, is uniquely related to the bed shear stress, τ_b, by a logarithmic-normal relationship. For the different sediment suspensions tested, while the standard deviation, σ_y, of the logarithmic-normal relationship remains constant, the geometric mean, $(\tau^*_b - 1)_{50}$, which is the value of $(\tau^*_b - 1)$ corresponding to $C^*_{eq} = 0.50$, and where $\tau^*_b = \tau_b/\tau_{bmin}$, is strongly related to the minimum bed shear stress, τ_{bmin}, below which all the sediment eventually deposits. Moreover, both $(\tau^*_b - 1)_{50}$ and τ_{bmin} appear to be correlated to the Cation Exchange Capacities of the sediments used.

MEHTA, A. J., and PARTHENIADES, E. 1979 (Apr). "Kaolinite Resuspension Properties," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 105, No. HY4, pp 411-416.

The phenomena of erosion and deposition of fine, flocculated, cohesive sediments have been studied by the writers during the past several years. The first investigations, which were limited primarily to the erosion phase, were conducted in an open flume with recirculating water at ocean salinity with natural silty-clay sediments. These investigations revealed a number of erosional and depositional characteristics of cohesive sediments, and led to an analytic model giving the rates of erosion in terms of the bed shear stress and certain parameters incorporating the physico-chemical properties of the clay-water system. Among the more important erosional characteristics were: (a) The constancy of the rate of erosion for constant flow conditions and bed properties; (b) the independence of the initiation and the rate of erosion from the macroscopic shear strength of the bed for low- to medium-strength clays; and (c) the absence of simultaneous erosion and deposition. Since then, these properties have been further examined with the aid of a new model of flow-bed sediment interaction.

MEHTA, A. J., WECKMANN, J., and CHRISTENSEN, B. A. 1981 (Jul). "Sediment Management in Coastal Marinas: A Case Study," International Symposium on Urban Hydrology, Hydraulics, and Sediment Control, pp 83-90, Lexington, Ky.

Marinas which are inadequately designed against sediment intrusion are common, and Florida, which has in excess of 600 coastal marinas, is no exception. In this paper, the problem of marina sedimentation has been described with special reference to a basin situated near a tidal waterway in Florida. Steps necessary to carry out a comprehensive sediment management program in order to minimize sedimentation have been noted. In the case studied, two sediment sources were identified, namely intrusion from the estuary via the basin entrance and the backfill behind the basin bulkhead. Whereas the first is a settling basin type phenomenon, the second was found to be due to piping. The selected methodology for evaluating a long-term sediment budget for the marina has been described. Computations for redesigning the bulkhead and a proposed new method involving redesigning the entrance to minimize sedimentation based upon hydrodynamic principles have been summarized.

MEHTA, A. J., PARTHENIADES, E., DIXIT, J. G., and McANALLY, W. H. 1982 (Aug). "Properties of Deposited Kaolinite in a Long Flume," Applying Research to Hydraulic Practice, P. E. Smith, ed., pp 594-603.

Recent results from three laboratory tests on the deposition of kaolinite in water in a 100-m-long flume are reported. In each test, suspended sediment was allowed to deposit in the flume at selected values of discharge and depth of flow. The undeposited portion of the sediment passed out of the flume at the downstream end. Sediment accumulated in each 12.2-m segment of the 100-m-long deposited bed was next resuspended in a 1.5-m-diameter and 0.21-m-wide annular rotating fume, and was allowed to deposit under a constant applied bed shear stress. The rates of deposition are found to follow a law similar to that derived from basic laboratory investigations of the depositional behavior of cohesive sediments reported previously. Parameters characterizing this law are found to exhibit significant variation along the length of the 100-m-long flume, implying a corresponding variation in the rates of deposition of the suspended aggregates. Differences in aggregate properties resulting from corresponding differences in the particulate composition of the aggregates appear to be a causative factor. The results elucidate a mechanism for sediment sorting which commonly occurs in muddy estuaries.

MEHTA, A. J., PARCHURE, T. M., DIXIT, J. G., and ARIATHURAI, R. 1982. "Resuspension Potential of Deposited Cohesive Sediment Beds," Estuarine Comparisons, V. S. Kennedy, ed., pp 591-609, Academic Press, New York.

Surficial layers of fine, cohesive sediment beds in estuaries typically consist of partially consolidated sediments deposited from flow. Such layers tend to have a high water content and exhibit a nonuniform variation of the shear strength with depth. Predictive modeling of estuarial fine sediment transport requires an appropriate description of the erosive behavior of deposited beds. Most available descriptions however are based on laboratory tests using mechanically placed beds. Such beds possess relatively uniform properties and are representative of settled, consolidated estuarial beds. A laboratory test methodology for investigating the resuspension potential of deposited beds is described. Tests using beds of kaolinite show that the rate of erosion varies exponentially with the excess bed shear stress. The influence of bed consolidation time and water chemistry on the rate and the critical shear stress for erosion has been investigated. The derived expression for the rate of erosion can be suitably incorporated in the resuspension routines for estuarial fine sediment transport models.

MELTON, B. K., and FRANCO, J. J. 1979 (Mar). "Shoaling in Harbor Entrances; Hydraulic Model Investigation," Technical Report No. HL-79-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

This report covers the results of a general investigation to determine and demonstrate some of the principles involved in shoaling in harbor entrances and some of the factors to be considered in the development of solutions to the problems. The model used was not a reproduction of a reach of any stream but was designed to fit in an existing facility and provide for two bends and a straight reach between the bends. The model was of the movable-bed type with scales established arbitrarily as 1:400 horizontally and 1:100 vertically. Tests were conducted with the harbor entrance located along the concave bank of the upper bend, in the straight reach, and along the convex bank of the lower bend simultaneously.

MICHAELS, A. S., and BOLGER, J. C. 1962 (Feb). "Settling Rates and Sediment Volumes of Flocculated Kaolin Suspensions," Industrial and Engineering Chemistry, Vol 1, No. 1, pp 24-33.

This study investigated the settling rates and sediment volumes of aqueous, flocculated kaolin suspensions as functions of kaolin concentration, container dimensions, and chemical composition of the aqueous phase. Equations which correlated the data were derived, based on a structural model which assumed that in a flocculated suspension the basic flow units are small clusters of particles (plus enclosed water) called flocs. These flocs retain their identity under the mild forces experienced in gravity settling. At low shear rates, the flocs group into clusters of flocs called aggregates. The aggregates may form networks which extend to the walls of the container and give the suspension its plastic and structural properties.

MIGNIOT, C. 1977. "Effect of Currents, Waves and Wind on Sediment," *La Houille Blanche,* Vol 32, No. 1, pp 9-47.

The purpose of the collection of formulas and graphs offered in this discussion on effects of currents, waves, and wind on sediments is only an attempt to provide engineers and technicians, who will have to deal with the sedimentary transport problem, with a certain number of practical application features making it possible to ascertain ranges of values for the phenomena involved in relatively simple cases.

While purposely leaving aside purely theoretical considerations on sedimentary transport, a priority has been assigned to the description of physical phenomena bearing on sediment transport. In the same way, rather than setting up very elaborate formulas, preference was given to simplified readily usable formulas, illustrated with graphs and actual in-nature examples were collected over several decades.

MIGNIOT, C. 1968. "A Study of the Physical Properties of Various Forms of Very Fine Sediment and Their Behavior Under Hydrodynamic Action," La Houille Blanche, No. 7, pp 591-620.

A comparative study of the physical properties of pelitic sediment of the mud, silt, or sludge type and of its behavior under hydrodynamic action shows that, in spite of the complexity of the phenomena involved, there are a certain number of simple relationships between the various representative parameters for soil-water complexes.

It is essential to know the mineralogic, chemical, and granulometric characteristics of elementary particles to determine the origin of a given deposit and make assumptions as to how it will settle in a given point. Confirmations can be obtained through the detection of natural tracers consisting of certain trace elements contained in the sediments and through modern radioactive tracing methods.

In all cases, flocculation, settling, rigidity, and viscosity of the deposits appear to be the physical parameters characteristic of the evolution of soil-water complexes under the action of various hydrodynamic agents. It is pointed out, however, that these parameters are still hard to determine accurately and that their quantitative values still depend on measurement conditions and should be extrapolated with great caution before being applied to more general cases.

MILLER, J. A. 1975. "Facies Characteristics of Laguna Madre Wind-Tidal Flats," Tidal Deposits, R. N. Ginsburg, ed., Chapter 8, pp 67-73, Springer-Verlag, New York.

Laguna Madre Flats is a predominantly terrigenous, wind-tidal flat forming a land bridge between Padre Island and the mainland on the south Texas coastal plain. The flats are approximately 20 km long and 10 km wide.

Clay and algal-mat sequences are well developed on those frequently flooded portions of the wind-tidal flat. The clay and algal laminae are commonly contorted and disrupted by desiccation, gypsum crystallization, and burrowing. Gray subtidal sand containing gypsum sand crystals and poorly defined clay laminae underlies the clay and algal zone.

In the more restricted and arid portions of the flats, gypsum becomes a prominent sediment constituent, but no anhydrite has been detected in any of the samples. Investigations by Masson, Fisk, and the author indicate that nearly all of the gypsum develops in or beneath the surface sediments by precipitation from interstitial brines. As might be expected, the gypsum occurs in a variety of forms, dependent upon the conditions of precipitation and the composition of the surrounding sediments.

The distribution of the carbonates and the relative proportions in which they occur are quite complex. Most of them are found in association with clay and algal materials, with the algal mats seeming to be the more important. Aragonite formation appears to be favored in sediments that are predominantly sand, with moderate to minor quantities of clay, algae, and gypsum. Conversely, dolomite seems favored in sediments dominated by clay, algae, and gypsum, and containing only minor amounts of sand.

Although some bacteriologic work has been done in the area, the extent of bacterial activity in Laguna Madre sediments is largely speculative. The author's observations, geochemical data, and mineralogic analyses indicate that bacteria probably play an active role in the production of interstitial gases and that they may strongly influence local Eh and pH conditions. Furthermore, it is quite likely that the formation of carbonates, gypsum, and iron sulfides is promoted by the action of ammonifying and sulfate-reducing bacteria.

MILLIMAN, J. D., HSUEH, Y., HU, D., PASHINSKI, D. J., SHEN, H., YANG, Z., and HACKER, P. 1984. "Tidal Phase Control of Sediment Discharge from the Yangtze River," Estuarine, Coastal and Shelf Science, Vol 19, pp 119-128.

Tidal phase plays a major role in controlling sediment discharge from the Yangtze River estuary in eastern China. Direct measurements indicate that during spring tide in mid-November 1981, approximately three times the sediment passed down the main channel of the river as during the next neap tide, three days later. The estuary presumably acts as a conduit for riverine sediment during spring tide but as a sink during neap tide. Tidal phase control of sediment discharge appears to be primarily dependent upon tidal range relative to estuarine depth rather than river discharge or absolute tidal range per se.

MILNE, I. H., and EARLEY, J. W. 1958 (Jun). "Effect of Source and Environment on Clay Minerals," Bulletin of the American Association of Petroleum Geologists, Vol 42, Part I, pp 328-338.

The clay mineral assemblage in an area of active deposition is dependent largely on the character of the source area. This conclusion is based on a study of the clay mineralogy of sediments of the lower Mississippi River, the active delta region, the St. Bernard Sub-delta, and the Mississippi Sound-Mobile Bay area. Montmorillonite, the predominant clay mineral in the Mississippi River and delta sediments, is apparently the stable product of soil development and rock weathering in the drainage basin of the Mississippi River. The sediments of the Mississippi Sound-Mobile Bay area, east of the Mississippi delta and derived ultimately from the Appalachian Province, contain considerably more kaolinite. Transition zones between the two sediment types can be differentiated.

Alteration of clay minerals in a depositional area can be expected where the sedimentation rate is low and sufficient time is available for chemical equilibria between the sea water and the clay minerals. In areas of rapid mud deposition, the blanketing effect of overlying clay material probably reduces the chemical interaction to that which is possible between the clay and the entrapped water.

The Mississippi River sediment carried into the saline environment, does not show significant changes in clay mineralogy except along the shelf edge. In this area of slow sedimentation, illite (clay mica) is more prominent. In the St. Bernard Sub-delta, a non-active depositional area for the last 400 years, alteration or diagenesis of the contained clay minerals appears to be associated with evidence of exposure of the sediment to surface oxidizing conditions. In the Mississippi Sound-Mobile Bay area the clays alter rapidly upon entering the saline environment. A part of the clay mineral assemblage has been attributed to a montmorillonite-organic complex, which appears to be modified or destroyed in the all saline sea-water environment.

An examination of buried muds of Tertiary age has indicated that little or no alteration of clay minerals takes place in shales to a depth of several thousand feet. However, clay minerals contained in sands may be greatly altered during burial.

MITCHELL, B. T. 1952 (Feb). "First Interim Report on Study of Sediment Transportation Characteristics of Natural Streams," US Army Engineer District, Omaha, Missouri River Division, pp 10-34.

The principal results of the work during the July-October period were the acquisition of data from the flat portions of the streambed, which could be evaluated more clearly than those from the sand-wave areas, and the extension of knowledge of the sediment and hydraulic parameters which were being measured. No particular improvement was made in anchoring and other boat-handling techniques. The emphasis on closer vertical spacing of observations of velocity and sediment near the streambed was readily apparent in the plots of vertical distribution.

MITCHELL, J. K. 1960 (Jun). "Fundamental Aspects of Thixotropy in Soils," Journal, Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol 86, No. SM3, pp 1586-1626.

Thixotropic phenomena are described and previous investigations on the behavior of thixotropic systems are summarized. The complex nature of the phenomena is pointed out, as well as the fact that thixotropy is of quite general occurrence in fine-grained materials.

A hypothesis for thixotropic behavior based on initial nonequilibrium of interparticle forces after remolding or compaction, and the effects of this nonequilibrium on subsequent structure changes within the soil, is offered as one possible explanation of the phenomenon. Experimental results are present which are consistent with the hypothesis.

Some of the practical aspects of thixotropy are pointed out, and it is suggested that thixotropic strength increases warrant consideration in design provided they are accurately evaluated.

MODARRESI, H. G. 1968. "Settling Velocity Tube Apparatus for Successive Determination of Fall Velocities of Sand Size Particles," Journal of Sedimentary Petrology, Vol 38, No. 4, pp 1354-1358.

Conventional sedimentation methods are impractical for determining settling velocity distribution of a sand sample limited to a few hundred grains. The settling velocity distribution of a very small amount of sand grains may be determined accurately in a one-step operation using a modified Hand settling tube and an electrical event recorder.

MOHAMMED, A. I. Y., GUNAJI, N. N., and SMITH, P. R. 1975 (Jul). "Turbulent Flow of Power-Law Fluids," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 101, No. HY7, pp 885-899.

The objectives of the present study are as follows: (a) to develop a generalized momentum transfer hypothesis applicable to both Newtonian fluids and purely viscous non-Newtonian power-law fluids for steady incompressible turbulent flow through circular conduits; (b) to demonstrate that, while the magnitude of the viscous and turbulent stresses may vary with the position in the flow field, both are operative throughout and that such an approach produces the correct velocity distribution in the flow field; and (c) to develop an explicit expression for the friction factor-Reynolds number relationship that is valid for Newtonian fluids and non-Newtonian power-law fluids.

MOHR, A. 1981 (Nov). "Sediment Control Through Dredging," Estuarine Research Federation Conference, Gleneden Beach, Oreg.

Sediment control is necessary, but its traditional benefit-cost comparison is no longer the sole criterion. It can be achieved in various forms of river training and dredging.

Dredges are divided into hydraulic and mechanical dredges, their dominant types being the cutterhead, hopper, and endless-chain bucket dredges. The operating principle of hydraulic dredges is more complex than that of mechanical dredges and subject to several constraints. Yet, nearly all dredging in this country is hydraulic with a more even distribution in the rest of the world.

Dredged material density increases in importance due to increases in transport distances, environmental concerns, and fuel consumption. It also affects some sediment measurements which can be obtained in place or while the material is handled.

A typical dredging job may take one year from its inception to completion; however, dredging can be appreciably faster under emergency conditions. Comparing dredging to other forms of river training, no method is universally advantageous. They will continue to exist side by side and be decided upon on a case-by-case basis.

MONTES, J. S., and IPPEN, A. T. 1973 (Jan). "Interaction of Two-Dimensional Turbulent Flow with Suspended Particles," Report No. 164, Massachusetts Institute of Technology, Cambridge, Mass.

The problem of flow of suspensions of heavy sediment is considered first in a historical perspective, where an account of earlier efforts in this field are given. The most relevant advances are presented chronologically from the European engineering concepts of the XIX Century to the basic, physics-oriented view of the interaction between sediment and fluid flow of the present.

In a problem of such complexity, experiments are needed to guide the theoretical development. Consequently, a set of runs designed to complement, rather than repeat previous efforts in this field, was undertaken in the 64-ft-long sediment flume of the R. M. Parsons Hydrodynamics Laboratory. The details of the experimental procedure and data reduction are discussed.

Equations of motion are derived for the mixture of sediment and fluid based on a reasonable hypothesis of the sediment transport velocity. The problem of integrating this set of equations, the so-called "closure" problem, is then undertaken. It is argued that the state of the art in the measurement of turbulent quantities with flow in suspensions does not allow for transport equations for the turbulent correlations. Hence, a simplified mixing length model which takes into account both density and velocity fluctuations is proposed. As this model requires a rather exact description of the concentration profile near the bottom of the channel, a new empirical concentration profile was developed, which gave $dc/dy = 0$ at the bottom and shows an exponential decay at some distance above. The subsequent integration of the momentum equations is shown to be in reasonable agreement with the experimental evidence. Two other methods are also compared with the same experimental data. They also show a fair measure of agreement. It is claimed, however, that the present hypothesis dispenses with the need for auxiliary empirical correlations found in the methods of Ordonez and Einstein-Chien and that it is possible to extend it to the field of graded mixtures.

Two other current problems in the literature of suspended sediment transport are briefly examined: the behavior of the ratio between the eddy diffusion and momentum diffusion coefficients, and the problem of friction factors in open channels. It is shown that in order to have equilibrium between the sediment dispersion rate by turbulence and the settling of the particles due to gravity the ratio of sediment to momentum transfer coefficient $\varepsilon_s/\varepsilon_m$ must increase with the sediment diameter. The friction factors with sediment in suspension are shown to be always larger than pure fluid. The exceptions to this rule and possible explanations for the opposite findings of Vanoni are discussed.

MOORE, G. T. 1970 (Feb). "Role of Salt Wedge in Bar-Finger Sand and Delta Development," The American Association of Petroleum Geologists Bulletin, Vol 54, No. 2, pp 326-333.

A linear continuous deposit composed primarily of fine and very fine sand which occupies the channel and distributaries of the lower Mississippi River is termed a "bar-finger sand." One explanation relates the origin to deposition of the thick sand units at the mouth of the river as distributary mouth bars. This process is acknowledged as the initial phase; however,it is postulated that development of these sands continues after the river has prograded beyond the original site of bar formation. This continuing process is postulated to be related directly to the annual discharge pattern of the river.

The intrusion of salt water into the river channel during periods of less than maximum discharge reduces the current and carrying power of the river directly above its bed and causes deposition of the coarser fractions. This process is postulated to be the other major cause for the deposition of large amounts of sand along the channel. Inasmuch as this phenomenon occurs during much of the year, a net buildup of sediment occurs. Recognition of the importance of bar-finger sands may aid the exploration geologist in his quest for petroleum in areas where the deltaic process has been active.

MORGAN, J. P. 1967. "Ephemeral Estuaries of the Deltaic Environment," Estuaries, Publication No. 83, pp 115-120, American Association for the Advancement of Science, Washington, DC.

Three distinct geomorphic estuarine types can be recognized in the environs of major river deltas. Illustrations have been chosen from the Mississippi Delta, a low-tide and low-energy environment, and the high-tide regime of the Ganges-Brahmaputra system. Other areas, subject to conditions between the extremes described, would display intermediate variations in effects of the processes considered.

All deltaic estuaries are a product of the delicate balance which exists between coastal progradation through sedimentation, coastal retreat under wave attack, and variations in sea level. The present happens to be a time of stability or near stability of sea level, consequently minor subsidence in deltaic land elevation through compaction or downwarping can lead to the formation of estuaries.

Currents resulting from a significant tidal range modify deltaic physiography by channel erosion and interdistributary deposition. Tidal processes serve to mask or obscure the estuarine types of the low tidal deltaic environment. In either case, estuarine morphology of the deltaic environment is subject to rapid modification, as are deltas themselves. From the standpoint of geologic time, deltaic estuaries are ephemeral in nature, but, when considering the relatively short span of time involved in recorded human history, these complex changing environments acquire great significance.

MOSSOP, G. D., and FLACH, P. D. 1983 (Aug). "Deep Channel Sedimentation in the Lower Cretaceous McMurray Formation, Athabasca Oil Sands, Alberta," Sedimentology, Vol 30, No. 4, pp 493-509.

In the region of the Athabasca Oil Sands, Alberta, the Lower Cretaceous McMurray Formation comprises 50-80 m of uncemented quartz sand and associated shale, saturated throughout by bitumen. The sediments are dominantly of continental origin, except in the uppermost parts of the formation where sedimentation was influenced by the encroaching boreal sea.

In most outcrop and mine face exposures of the McMurray formation, a sequence of three facies is recognized. In ascending order these are: (a) an erosionally based thick-bedded sand facies, 2-20 m thick, dominated by large-scale trough cross-beds; (b) an epsilon cross-stratified facies with solitary sets up to 25 m in thickness, consisting of decimetre-to metre-thick couplets of sand/mud, with depositional slopes of 8 to 12° and palaeocurrent indications parallel to the strike of the epsilon cross-set; and (c) a horizontally bedded argillaceous sand facies up to a few metres thick. The three-fold sequence is interpreted as a single upward-fining cycle of channel sedimentation, the trough cross-bedded sands resulting from channel bottom deposition, the epsilon cross-strata accumulating by lateral accretion of channel point bars, and the upper argillaceous sand representing floodplain sedimentation. Where the McMurray Formation is relatively thin (less than 50 m), virtually the entire formation is commonly composed of a single upward-fining channel deposit.

Details of the size and physiographic setting of the channels are somewhat uncertain, but the present evidence suggests that the epsilon-dominated McMurray Formation sequence in the Athabasca Deposit region represents the coastal plain culmination of a very large fluvial drainage system.

MOTAYED, A. K., and KRISHNAMURTHY, M. 1980 (Jun). "Composite Roughness of Natural Channels," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 106, No. HY6, pp 1111-1116.

Channel sections with roughnesses varying laterally along the wetted perimeter are often encountered in design problems and laboratory experiments. In all such problems, computations of equivalent roughness for the whole section are sometimes necessary. Various formulas to compute this equivalent or composite roughness can be found in the literature. To this date, however, very little has been done to evaluate these formulas using natural stream data. The paper reports on an investigation to evaluate some of these existing formulas to compute the composite roughness with data from natural stream channels.

MOTTA, V. F., and BANDEIRA, J. V. 1974. "Comparison Between the Results of Littoral-Drift Computations and Cubature of Deposits in a Dredged Channel," Proceedings of the 14th Coastal Engineering Conference, Vol II, pp 726-740, Copenhagen, Denmark.

The total annual volume of littoral drift on either side of the mouth of Sergipe estuary, in the northeast of Brazil, has been determined by applying Caldwell's, Castanho's, and Bijker's methods to the wave characteristics that had been recorded at a twenty-metre depth of water, over a whole year, for the design of an offshore oil terminal.

The three computation methods yielded the same order of magnitude which was found to amount to about 800,000 m^3/year. The dominant drift is southwestward, and its predicted amount is 660,000 m^3/year. It was also found that, although the three methods lead to total results of the same order of magnitude, they do not agree as to the variation of littoral drift over the year for the same waves.

An eight-metre-deep shipping channel has been dredged across the bar. The channel was surveyed in December 1971 and August and December 1972, and a cubature of the deposits was made after the littoral-drift computations had been carried out. As the latter had been performed on a monthly basis, a comparison became possible between predicted and actual volumes of deposits for the same lengths of time.

The predicted volumes for the whole year were found to be from 34 to 46 percent greater than the actual results. However, for the time interval August through December 1972, a remarkable agreement was found between predicted and actual results.

MURPHY, R. S., CARLSON, R. F., NYQUIST, D., and BRITCH, R. 1972 (Nov). "Effect of Waste Discharges into a Silt-Laden Estuary: A Case Study of Cook Inlet, Alaska," Publication No. IWR 26, Institute of Water Resources, University of Alaska, Fairbanks, Alas.

The fact that all of the Anchorage area's sewage flows untreated into Cook Inlet has scientific interest, particularly because of its effect on the environmental quality of inlet waters and adjacent beaches. In addition, when one realizes that approximately one-half of Alaska's population lives and works in the Anchorage area, this problem assumes a more immediate significance. What environmental effects can be expected if significant quantities of domestic sewage are discharged into a far northern estuary having a great quantity of glacial silt? And what is the present environmental state of Knik Arm as a result of the historical discharge of all of Anchorage's wastes? These were the questions this report sought to answer. The first has significance for many areas along the Alaska coastline. The second is directed specifically to Knik Arm.

While the freshwater input is significant, it does not appear to be appreciably important to waste discharge, primarily because the waste decays. This decay, in combination with the intense mixing, results in little difference in the sewage concentration upstream and downstream from the outfall. However, freshwater advection does affect the concentration of conservative substances. In fact, it was this effect which enabled the estimation of the diffusion coefficient in this area.

A one-dimensional model adequately explains many of the effects of waste discharge into the water mass. It clearly illustrates the effects of various decay constants on the distribution of wastes discharged into the inlet. The two-dimensional model improves the estimate somewhat and illustrates the inadequacies of the one-dimensional model, especially in the vicinity of the outfall.

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NAHON, D., and TROMPETTE, R. 1982 (Feb). "Origin of Siltstones: Glacial Grinding Versus Weathering," Sedimentology, Vol 29, No. 1, pp 25-35.

Siltstones are unusual rocks. They are mainly made up of quartz. Glacial grinding is considered by some authors to be the main, or even the only, process generating silt. This is supported by: (a) the presence of silt in basal tills from present ice-caps and, above all, (b) the volumetric importance of Quaternary loess. However, ancient glaciogenic sediments contain only a little silt scattered in the matrix of tillites, or forming thin intercalations in pro- and periglacial deposits. These siltstones represent less than 5 percent of the total volume of Upper Proterozoic and Upper Ordovician glaciogenic sequences of West Africa.

On the other hand, silt is abundant in weathering profiles of tropical, equatorial, and mediterranean zones. This silt is generated by splitting of minerals, mainly quartz, inherited from the parent rock. Quartz grains are partly dissolved in situ and their fragments cemented by iron oxi-hydroxides in tropical and equatorial zones and by calcite in mediterranean zones. Silt is particularly abundant in tropical soils, comprising up to 50 to 75 percent. Secondary dissolution of the iron or calcite matrix induces disaggregation of these soils and the release of silt which is later reworked and concentrated by wind or running water.

Weathering processes, and especially those operating in tropical zones, are the main phenomena generating silt. Glacial grinding would generate only a little silt. A large part of the material of Quaternary loess may be derived from glacially reworked weathering profiles.

NEDECO. 1965 (Jul). "A Study on the Siltation of the Bangkok Port Channel," Vol II, The Field Investigation, pp 7-291, Netherlands Engineering Consultants, The Hague, Holland.

The siltation study of the Bangkok Port Channel contains information on the siltation problem, its cause, channel maintenance, discharge modifications, and storage reservoirs. It also includes possible structures or increased channel dimensions on the salt intrusion in the Chao Phya.

NEIHEISEL, J. 1966 (Sep). "Significance of Clay Minerals in Shoaling Problems," Technical Bulletin No. 10, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The use of clay mineral ratios in conjunction with diagnostic silt and sand-size heavy minerals from bottom sediment samples within the physiographic units comprising the watershed which terminate in estuaries along the South Carolina and Georgia coast provides a process-response model capable of delineating the source, transportation direction, and manner of deposition of shoaling materials in a harbor area. Analysis of suspended samples obtained during the tidal cycle at stations from approach directions and within the estuary for composition, concentration, texture, and salinity also enables delineation of circulation patterns of the estuary.

The Piedmont and Tuscaloosa formation source clays of South Carolina and Georgia contain predominantly kaolinite and a sparseness of montmorillonite, whereas lower Coastal Plain clays consist largely of montmorillonite and subordinate amounts of kaolinite. The ratio of kaolinite/montmorillonite serves as an index in relating the source areas or determining whether a "mixed source" sediment occurs in an estuary. Hornblende in sand-size sediment is diagnostic of a Piedmont source and dispersal of sand-size materials from the source area.

A mineral locally abundant in an eroding formation in proximity to an estuary may constitute highly diagnostic "natural tracers." In the upper Cooper River, hydraulic scour is contributing dolomite rhombs from the Cooper marl formation of Tertiary age which is readily detected by analysis of suspended samples in Charleston Harbor. Such "point source" materials to an estuary along with salinity, velocity, suspended load measurements, sizing measurements, and composition analysis enable interpretation of estuary circulation and deposition.

The integrated approach has been applied successfully to such complex estuaries as Charleston and Brunswick Harbors. The method may be extended to the study of shoaling in other estuaries along the southeastern United States and to any estuary where diagnostic minerals occur which will reflect the source area in mineral ratios of the shoal sediment.

NEIHEISEL, J. 1959. "Sources of Shoaling in Charleston Harbor, Fourier Grain Shape Analysis: A Discussion," pp 666-670, Environmental Protection Agency, Washington, DC.

Fourier grain shape is a good technique, superior to any other on reflecting silt-sized material. It is no good for clays; X-ray diffraction is better. Clay mineral ratios show sources.

Dredging records are not good indicators of sedimentation rates because (a) several years are needed to detect shoaling changes, (b) there are no detailed records of man-made or natural disturbances, and (c) dredging operations are dependent on funding not shoaling.

NEIHEISEL, J., and WEAVER, C. E. 1967 (Dec). "Transport and Deposition of Clay Minerals, Southeastern United States," Journal of Sedimentary Petrology, Vol 37, No. 4, pp 1084-1116.

In the southeastern United States, kaolinite is the dominant clay mineral and hornblende the dominant heavy mineral in the Piedmont Province. Montmorillonite is the major clay mineral in the Coastal Plain. Only minor amounts of hornblende are found in this latter province. Illite is the dominant clay mineral in the Continental Shelf sediments off the coast of this area. Rivers draining the two continental source areas carry diagnostic suites of sediments.

In the rivers and estuaries, the ratio kaolinite/montmorillonite serves to identify the relative proportion of clay-size sediment derived from the two source areas. Hornblende can be used to follow the dispersal of sand-size materials. Illite can be used to determine the offshore contribution to the estuaries.

Much of the sediments in Port Royal Sound, fed only by small Coastal Plain rivers, is carried in from the Continental Shelf by flood tides. The distribution of the various minerals suggests that Coriolis force is a major factor in determining the dispersal pattern in this estuary and in Charleston Harbor.

Both bottom and suspended sediments from Charleston Harbor and vicinity were studied. This information was used in conjunction with salinity and velocity data to determine the source of the sediment and the circulation and depositional pattern inside and outside the harbor. This study shows the effects of partially diverting a major Piedmont River (Santee) into a harbor which was formerly entirely within a Coastal Plain drainage basin.

A study of Brunswick Harbor, which is situated within a Coastal Plain drainage basin, showed that it obtains much of its sediment from a Piedmont River (Altamaha) via a salt marsh stream running parallel to the coast.

NELSEN, TERRY A. 1983. "Time- and Method-Dependent Size Distributions of Fine-Grained Sediments," Sedimentology, Vol 30, pp 249-259.

With increased interest in fine-grained sediments, it is imperative that a firm basis exist for comparative studies of these cohesive sediments. In this study the size distributions of continental slope and rise muds are shown to be dependent on both method and duration of sample pretreatment. Statistical analysis of 171 size distributions indicates that of the four most frequently used sample preparation methods (soak, stir, shake, and ultrasonify) the time required to reach a 'terminal' distribution beyond which no 'fine-shift' was detected varied from 15 minutes to >90 hours for a given sample solely as a function of preparation method. Data from this study also indicate that sample preparation by simple soaking alone will probably yield fine-grained sediments which, when analyzed by pipette or microsedimentation accumulation balance, undergo a continuous change in size distribution during analysis and may never reach a 'terminal' distribution during the analysis time. On the other hand, stirring and ultrasonification were shown to be the most rapid and consistent methods for obtaining a sample's 'terminal' distribution.

NELSEN, B. W. 1958 (Oct). "Clay Mineralogy of the Bottom Sediments, Rappahannock River, Virginia," Clays and Clay Minerals, Proceedings, Seventh National Conference on Clays and Clay Minerals, pp 135-147.

Bottom sediment clay mineral assemblages from the Rappahannock River and estuary contain kaolinite, illite, unorganized illite, dioctahedral vermiculite, 12.4Å montmorillonite, 14.2Å montmorillonite, chlorite, feldspar, and quartz. The X-ray diffraction characteristics of these species and their thermal modifications at 25 to 500°C are described and illustrated. Progressive changes in the mineralogical composition of bottom sediments occur between the freshwater and saline-water portions of the Rappahannock system. Chlorite and feldspar occur exclusively in the saline portions of the estuary. Illite shows progressive increase in crystallization quality. There appears to be less kaolinite, proportionately, in the estuarine sediments of the most saline zone. X-ray diffraction diagrams showing these progressive changes are illustrated.

NICHOLS, M. M. 1974. "Development of the Turbidity Maximum in the Rappahannock Estuary, Summary," Proceedings, International Symposium on Interrelationships of Estuarine and Continental Shelf Sedimentation, No. 7, pp 19-25, Bordeaux, France.

The dynamic behavior of the turbidity maximum in the Rappahannock estuary of the Chesapeake region has been traced through a full life cycle with changes in river inflow and haline mixing. At all levels of inflow the maximum resides within the estuary. Its locus lies just upstream of the 1 percent isohaline and its position shifts upstream with penetration of the salt intrusion. Development follows a sequence beginning with high inflow or a major seaward surge of turbulent flood water: (a) formation of an enriched turbid aureole with near-surface and near-bottom maxima and a lean core at mid-depth, (b) progressive upstream migration and vertical homogeneity in a narrow zone, (c) local intensification near the bottom with a partly layered structure, and (d) slow decay and dispersion over a broad zone. The maximum reappears with each seasonal (spring) inflow and it subsists for a life span of 4 to 16 weeks as estuarine mixing increases. Time-series observations of velocity over 16 to 26 tidal cycles through the maximum define a near-bottom convergence or node where river and estuarine flow meet. Measurements of residual sediment transport show a significant amount of suspended sediment accumulates in the maximum, approximately four times the river load, despite losses by downstream advection in near-surface water, diffusion and settling-out on the bottom or in bordering marshes. The observations point to river inflow as the chief factor controlling position of the maximum and its intensity is supported by the strength of the river-estuarine convergence and by the supply of river-borne sediment including resuspended and redistributed material.

NICHOLS, M. M. 1972. "Sediments of the James River Estuary, Virginia," The Geological Society of America, Inc., Memoir 133, pp 169-212.

The James River estuary of the Chesapeake Bay region follows the course of a former river valley drowned within the last 9,000 years by the most recent rise of sea level. The floor is shaped into a central channel bordered by submerged shoals. Observations show suspended sediment is transported mainly by alternating tidal currents and secondarily by the net nontidal estuarine circulation. Transport results in a sequence of grain size distributions reflecting the mixing of two textural end members, clay and sand.

Silty clay is deposited in the river and upper estuary, whereas sand occurs near the mouth. Transitional types, clayey sand sand-silt-clay, predominate in the middle estuary. Additionally, biogenic materials, oyster shells and fecal pellets, and small amounts of residual components eroded from older deposits are mixed into the sediments by currents, waves, and organisms. Bottom sediment types vary widely according to local relief, to varying intensity of environmental processes, and to changing rates of supply from different sources.

Deposition is greatest in the middle estuary where salinity ranges from 5 to 14 parts per thousand. An elongate zone of relatively high deposition in the lower estuary corresponds to the intersection of the level of no-net-motion with the bottom. Despite substantial infilling, it is believed the estuary is maintained by the continued rise of sea level and by currents that flush part of the river-borne load through the estuary.

NICHOLS, M. M., and ELLISON, R. L. 1967. "Sedimentary Patterns of Microfauna in a Coastal Plain Estuary," Estuaries, G. H. Lauff, ed., American Association for the Advancement of Science, Publication No. 83, pp 283-288.

The patterns of microfauna in the Rappahannock estuary appear to be related to different types of estuarine water. Although the facies, as established by standing crops of microfauna, correspond with biotopes of the overlying water, certain aspects of the distributions suggest that transportation by currents and varying rates of sedimentation are also operating.

The rate of sedimentation certainly may be an important factor influencing the relationship between the distribution of living Foraminifera and the distribution of total tests. However, relative rates of sedimentation, as determined by using live/total ratios, and those determined from successive changes of depth on hydrographic charts during the periods 1855-1909-1955 show little relationship. Nevertheless, the middle estuary, just downstream from the gradient zone, appears to be one of relatively rapid sedimentation. The rapid accumulation on shoals represents the river-borne bed-load deposition delineated by Nelson (personal communication), whereas the high accumulation in the basin is associated with deposition of a fraction of the river-borne suspended load.

Standing crops of Foraminifera may change in size and position from year to year. However, an abundance of empty tests at a specific station apparently is not related to a large standing crop at the station in the previous year.

NICHOLS, M., FAAS, R., and THOMPSON, G. 1979 (Apr). "Estuarine Fluid Mud: Its Behavior and Accumulation," R & D Project No. 1T161102BH57-01, US Army Research Office, Research Triangle Park, NC.

A study of fluid mud in Virginia estuaries was conducted to determine how the mud accumulates in a dynamic tidal flow regime. The mud occurs as lenses and blanket deposits in zones of fast sedimentation on channel floors and in the turbidity maximum zone. Viscosity measurements indicate resuspension potential of the mud is greater in the turbidity maximum than elsewhere.

Time-series measurements over a tidal cycle at 6 cm above the bed show that stress increased linearly with acceleration of mean current but lagged maximum current velocity during deceleration of tidal currents. Fluid mud-flow interactions are primarily responsible for accumulation of the mud.

NICHOLS, M., and POOR, G. 1967 (Nov). "Sediment Transport in Coastal Plain Estuary," Journal, Waterways and Harbors Division, American Society of Civil Engineers, Vol 93, No. WW4, pp 83-95.

Along the mid-Atlantic coast, river valleys and inner margins of the shoreline are deeply indented and drowned by brackish waterways. The Rappahannock estuary is one of several subestuaries emptying into Chesapeake Bay. Like many estuaries in the region, the Rappahannock marks the submerged course of a former river valley cut into coastal plain sediments during a time when sea level was lower than at present. A narrow channel, 6 m to 9 m deep, meanders gently seaward through the upper estuary, and in the middle estuary the channel deepens seaward into a slot-like basin 20 m to 23 m deep, with a deep submerged sill at its mouth. Both the basin and the channel are bordered by submerged shoals averaging 2 m to 3 m deep.

The Rappahannock estuary offered several advantages for study. Its configuration is relatively straight and the bottom geometry is simple. Furthermore, the estuary is largely free of pollution and undisturbed by works of man, except for the harvesting of oysters. Therefore, natural processes could be studied prior to the development of engineering works which include a proposed dam and future channel deepening. Moreover, hydrodynamic conditions in the estuary are relatively mild, the tidal range is less than 80 cm and salinity varies within narrow limits, and these conditions, as well as the sediment characteristics, are fairly well known.

Between 1949 and 1961 the Chesapeake Bay Institute measured physical and chemical properties of the water at different seasons in the Rappahannock. Studies by Nelson covering the distribution of clay minerals and chemical characteristics of bottom sediments and suspensoids contribute important information pertinent to sediment source and transportation. This paper attempts to show how the patterns of sediment transport relate to the circulation in a coastal plain estuary.

NICHOLS, M. M., and THOMPSON, G. 1973 (Jul). "Development of the Turbidity Maximum in a Coastal Plain Estuary," US Army Research Office, Durham, NC.

A study of the turbidity maximum in the Rappahannock estuary, Virginia, was conducted to determine how high concentrations of suspended sediment accumulate to form a maximum.

Time-series observations of current velocity, salinity, and suspended sediment over 8 to 18 tidal cycles reveal that the maximum forms in a convergence of bottom residual currents near the transition between fresh and salty water. Sediment supplied mainly by the river is transported into the convergence by density currents and accumulates since velocity is nearly zero and settling exceeds upward mixing.

The maximum forms in the middle estuary after freshet or flooding and shifts upstream with a landward shift of the salt intrusion head and diminished river inflow. At the same time, its intensity is reduced by settling out, reduced strength of the convergence, and increased mixing. Prime prerequisites for development are a strong convergence and high river inflow.

The maximum modulates transport through estuaries to the sea by trapping materials and deposition. High turbidity can be alleviated by increased haline mixing and reduced inflow.

NUNAN, K. C., and KELLER, J. B. 1984. "Effective Viscosity of Periodic Suspension," Journal of Fluid Mechanics, Vol 142, pp 269-287.

The effective viscosity of a suspension is defined to be the four-tensor that relates the average deviatoric stress to the average rate of strain. The authors determine the effective viscosity of an array of spheres centered on the points of a periodic lattice in an incompressible Newtonian fluid. The formulation involves the traction exerted on a single sphere by the fluid, and an integral equation for this traction is derived. For lattices with cubic symmetry the effective viscosity tensor involves just two parameters. They are computed numerically for simple, body-centered, and face-centered cubic lattices of spheres with solute concentrations up to 90 percent of the close-packing concentration. Asymptotic results for high concentrations are obtained for arbitrary lattice geometries and found to be in good agreement with the numerical results for cubic lattices. The low-concentration asymptotic expansions of Zuzovsky also agree well with the numerical results.

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O'CONNOR, B. A. 1971. "Mathematical Model for Sediment Distribution," Proceedings, Fourteenth Congress, International Association for Hydraulic Research, Vol 4, pp 195-202.

A model describing the distribution of sediment in turbulent flow is presented which is based upon a finite difference solution to the general diffusion equation. Solutions in one and two dimensions are examined and various illustrations of them are given. The limitations of the models are discussed and it is concluded that laboratory and field data are required to test the usefulness of the present model approach.

O'CONNOR, B. A. 1975 (Jul). "Sediment Intrusion in a Tidal Lock," Proceedings, 16th Congress on Fundamental Tools to be Used in Environmental Problems, International Association for Hydraulic Research, Vol 3, Paper C35, pp 301-308.

The present paper describes modifications made to a two-dimensional mathematical model so that the dispersal of flocculated sediment can be described in tidal conditions. The modified model was also applied to a tidal flow involving density-exchange flow in Gladstone Lock on the Mersey Estuary (U.K.).

The model results show that errors due to neglecting changes in water depth are generally less than 10 percent. The use of diffusion coefficients in the model which are based on observed velocity profiles and a theoretical shear stress distribution for a density-dominated flow produces a more uniform distribution of sediment with depth. However, concentration levels are generally lower than in earlier tests. Better model/prototype agreement could be obtained by adjusting model parameters, but a lack of confirmatory field data prevents a check on the accuracy of such a process.

Model tests with a particle fall velocity varying with depth indicate a more uniform distribution of sediment with depth than when a constant value is used. There also appears to be few problems in using the model, but a better description of the physical process is required.

O'CONNOR, B. A. 1983 (Feb). "Sediment Transport in the Estuarine and Coastal Environment," The Dock & Harbour Authority, Vol LXIII, No. 747, pp 324-329.

This paper highlights the changes to flow and sediment movement that can be produced in estuaries and coastal waters as a result of engineering activity whose prime concern is the safe navigation of ships. The effects of engineering works, interfering with the boundary conditions or geometry of a particular area, are illustrated by practical examples from the U.K. and abroad and concern the construction of barrages, dock entrances and jetties, dredging works, and training schemes. These examples show that the effects can be both local, far reaching, and dramatic. This paper was presented at the Hydrographic Society's fourth biennial symposium, which was held at Southampton University in December 1982.

O'CONNOR, B. A., and TUXFORD, C. 1980 (Mar). "Modelling Siltation at Dock Entrances," Third International Symposium on Dredging Technology, Paper F2, pp 359-371, Bordeaux, France.

The paper describes the problems of constructing numerical computer models to simulate local erosion/deposition patterns near to dock entrances in wide shallow estuaries. Existing sediment modeling philosophy which has been used successfully for the construction of pollution models is shown, by reference to field data, to be inadequate. However, various suggestions are given whereby existing sediment models can be improved so as to produce more realistic answers.

The problems of devising suitable simplified test data for sediment models are also discussed and illustrated by application of a particular finite difference model to a laboratory test situation used by earlier workers. Good results are obtained from the model but equally good results are obtained by solution of a bed continuity equation, assuming suspended sediment concentrations are constant over the study area. This lattermost approach is called a zero-dimensional one and is shown to give realistic siltation answers for a dock entrance of the Forth Estuary.

It is concluded that existing sediment models need modification, that three-dimensional models avoid many of the difficulties associated with existing models, and that for some problems a simpler zero-dimensional approach can give useful answers.

O'CONNOR, B. A., and ZEIN, S. 1974 (Jun). "Numerical Modelling of Suspended Sediment," Proceedings, Fourteenth Coastal Engineering Conference, American Society of Civil Engineers, Vol II, pp 1109-1128.

The present paper describes the application of a two-dimensional numerical suspended sediment model to problems having analytical solutions, as well as to laboratory and field situations.

The model is based upon an implicit finite-difference solution to a two-dimensional (longitudinal and vertical) diffusion-advection equation for suspended sediment transport. Horizontal eddy diffusion is neglected in comparison with vertical diffusion, and vertical water motion is assumed negligible in comparison with the sediment fall velocity.

The various applications indicate that the greatest errors in the model are due to large spatial concentration gradients and that errors can be controlled by a suitable choice of space and time step. In addition, it is considered that the model has great flexibility and seems to have an acceptable level of accuracy, at least in the field situations tested, provided the physical parameters of the model can also be determined accurately.

O'CONNOR, D. J., and LUNG, W. 1981 (Feb). "Suspended Solids Analysis of Estuarine Systems," Journal, Environmental Engineering Division, American Society of Civil Engineers, Vol 107, No. EE1, Proceedings Paper 16014, pp 101-120.

One of the better understood aspects of estuarine hydrodynamics is that of the longitudinal circulation and mixing characteristics for partially-mixed estuaries as averaged over a tidal cycle. These features are also the key to the formation of turbidity maxima in estuaries. Based on the understanding of this circulation pattern, a two-layer salinity and suspended solids model is presented which includes a seaward advective flow in the surface layer, landward in the bottom layer, vertical advective flow, vertical dispersion across the layer interface, and the settling of suspended solids.

A simple hydrodynamic analysis is used to evaluate the horizontal and vertical transport coefficients. An empirical relationship with the Richardson number provides a preliminary estimate of the eddy dispersion coefficient from the eddy viscosity, determined in the velocity calculation. Methods of estimating the particle settling velocity are also presented.

Applications of the analysis to Sacramento-San Joaquin Delta and James River Estuary and Rappahannock demonstrate the overall validity of the approach. The distributions of salinity and suspended solids in all systems are reasonably reproduced.

ODD, N. V. M. 1982. "Mathematical Modelling of Siltation in Tidal Channels," <u>Hydraulic Modelling in Maritime Engineering,</u> Chapter 5, pp 57-64, Thomas Telford Ltd, London, England.

During the past decade, there has been a steady improvement in the understanding and theoretical description of sediment transport processes in tidal channels. This has made it possible to construct general purpose mathematical models, which can simulate the main features of the complete cycle of processes that determine the pattern of siltation in a narrow estuary. In the author's opinion, the practical application of the technique has now reached a stage when it can be employed as an almost standard procedure for investigating and solving siltation problems in narrow estuaries.

Port works often involve the construction of dredged re-entrances and turning basins which give rise to sudden expansions in an otherwise narrow channel. At present, this problem is usually handled by undertaking a separate calculation with a two-dimensional-in-plan model to calculate the distribution of siltation predicted by the channel model. Ideally one would prefer to connect the aforementioned channel models with a local three-dimensional model. However, as yet a suitable three-dimension sediment transport model has not been developed nor does the present generation of computers have a capacity to run two- and three-dimensional model simultaneously. The Hydraulics Research Station hope to overcome both these problems in the next few years.

ODD, N. V. M., and BAXTER, T. 1980 (Mar). "Port of Brisbane Siltation Study," Proceedings, Seventeenth Coastal Engineering Conference, Vol III, Chapter 142, pp 2377-2396.

The paper describes the constituent parts of a combined field and mathematical model investigation into the processes causing siltation in the Port of Brisbane. It describes the methods of collecting and using field data and laboratory results in conjunction with a variety of mathematical models which were employed to simulate and predict the interaction of tidal and fluvial flows, saline intrusion, and sediment transport in the Brisbane tidal river. A newly developed X-Z-T model was used to simulate the unsteady patterns of mud transport and siltation resulting from the interaction of tidal flows with short flashy fluvial floods, which are the main cause of shoaling in the port. The paper discusses the structuring of the investigation which involved a carefully phased schedule of desk, field, laboratory, and mathematical model investigations with the aim of solving the problem with minimum effort and cost.

ODD, N. V. M., and OWEN, M. W. 1972. "A Two-Layer Model of Mud Transport in the Thames Estuary," Proceedings, Paper 7517S, The Institution of Civil Engineers, pp 175-205.

The paper describes a two-layer mathematical model of mud transport in a well-mixed estuary. The main purpose of the model was to simulate mud transporting processes in the Thames estuary, and hence to determine the effects on the regime of siltation of continuous operation of various tidal barriers proposed for flood protection. The paper describes the basic reasoning which led the authors to construct a two-layer model; a method for calculating two-layer tidal flow with internal gravitational circulation induced by density gradients; methods for calculating the rates of erosion and deposition of mud based on field and laboratory experiments; and the application of the method of characteristics to solve the mass balance equations for the transport of mud suspended in two-layer flow. The paper discusses the verification of the calculation method based on data from the Thames estuary, including an analysis of the existing pattern of mud transport and siltation, as affected by two-layer tidal flow. Finally, the subsequent use of the model to predict the effect on the regime of siltation of continuous operation of half-tide barriers at Woolwich and Blackwall is dealt with.

ODD, N. V. M., and RODGER, J. G. 1978 (Mar). "Vertical Mixing in Stratified Tidal Flows," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 104, No. HY3, pp 337-351.

A recurrent problem in the numerical simulation of stratified tidal flows is representing the vertical exchange of momentum and solutes caused by turbulent fluctuations in the flow. In most calculations for practical engineering problems, the turbulent fluctuations have to be averaged out of the basic equations. The main turbulent terms are then represented as effective shear stresses (Reynolds stresses), τ_{zx} , or fluxes, F_z , which have to be evaluated in terms of the mean nonturbulent properties of the flow by the use of eddy viscosity or mixing length theories.

The results from mathematical models are sensitive to the type and form of the analytic functions used to represent the vertical distribution of eddy viscosity and mixing lengths. At present, mathematical modelers use various empirical functions, the coefficients for which are usually based on the same few documented cases of tide-averaged field observations, and are therefore inappropriate for predicting conditions within a tidal cycle. Some coefficients are based on laboratory experiments that were affected either by vertical acceleration effects such as in lock exchange flows or by viscous effects in experimental apparatus with low Reynolds Numbers. Thus, the quality of the mixing length or eddy viscosity functions now in use is generally inferior compared with the sophistication of the latest numerical techniques employed in tidal calculations.

The main purpose of the research was to improve the representation of vertical exchange processes in mathematical models used at the Hydraulics Research Station. This paper describes a set of analytical mixing length functions derived from the theories of Prandtl, Rossby and Montgomery, Kent and Pritchard, and Ellison as a means of calculating the internal shear stresses and vertical flux of solutes in gradually varying turbulent stratified flows. Field observations, made in a straight canalized reach of the Great Ouse estuary in the United Kingdom were used to determine the best-fit values of the empirical coefficients in the generalized relationships between the mixing lengths and the gradient Richardson Number.

OERTEL, G. F. 1974. "Hydrographic Framework of the Doboy Sound Estuary and Surveys of the Other Tidal Inlets along the Coast of Georgia," Skidaway Institute of Oceanography, Savannah, Ga.

Hydrographic and sedimentologic research was conducted during the summer of 1970 as part of a study to investigate the sediment budget at the entrance of the Doboy Sound estuary, Georgia.

The dynamic diversion of wind, wave, and tidal currents results in a predictable sand-shoal geometry at the entrance of the Doboy Sound estuary. Patterns of diversion developed in response to seasonal fluctuations in wind and wave approach interacting with inlet tidal drains. Mutually evasive flow paths of ebb and flood currents influence the formation of shoals adjacent to inlets.

Shoals at the entrance to Doboy Sound are partially exposed at low water and exhibit two trends. Three shoals form an elongate-offshore orientation that extends several miles seaward of the entrance. A fourth elongate shoal is oriented parallel to the beach approximately one-quarter mile offshore. During the summer months, sediment is transported in a closed system within these shoals, and there is essentially no sediment bypassing at the inlet although some bypassing apparently takes place seaward of the entrance. This condition results in lateral and vertical expansion of shoals and in sediment "starved" areas adjacent to shoals.

Tidal inlets along the Georgia coast have many hydrographic and geomorphic characteristics in common. However, estuaries with large fluvial sources of water are distinctly different in form and hydrographic character from tidal inlets without fluvial sources of low-salinity water. Sedimentation occurring in estuaries with large fluvial sources is generally a response to some form of bi-polar flow associated with a stratified water mass. The tidal inlets generally have large tidal drains that are diverted by mutually evasive tidal channels and inlet "water piles."

OFFICER, C. B. 1981. "Physical Dynamics of Estuarine Suspended Sediments," Marine Geology, Vol 40, No. 1/2, pp 1-14.

A review of the state of knowledge of the physical dynamics of estuarine suspended sediment distributions, transport, and erosion and deposition is given. Near bottom processes, net circulation effects, tidal effects, and plumes and fronts are discussed. Emphasis is placed on the several items that we do not fully understand or cannot describe in quantitative terms.

ORME, A. R. 1974 (Aug). "Estuarine Sedimentation Along the Natal Coast, South Africa," Technical Report No. 5, Office of Naval Research, Arlington, Va.

The character and materials of sedimentation in estuaries and lagoons along the 570-km Natal coast are described and analyzed. Sites examined include the Greater St. Lucia lagoon system with its 9 major contributing rivers, Richards Bay with its 2 main contributing rivers, and 28 rivers that discharge directly into the Indian Ocean without passing through an intermediate lagoonal filtering system other than their own estuaries. Discussion is based on field and remote sensing investigations and borehole data and is supported by pertinent maps and cross-sections. The nature and processes of sedimentation along the Natal coast are representative of events along more than 2000 km of African coast from central Mozambique to eastern Cape Province.

Fluvial deposits, ranging from large boulders to fine clays and typically dirty and rich in organic debris, occur throughout the estuaries but predominate in the inner areas. Lagoonal deposits, typically black organic silts and clays, accumulate toward the center of the lagoons and estuaries, or as backswamp deposits associated with reeds and mangroves to the side of the main channels. In shallow estuaries, lagoonal materials are commonly removed by major floods but in deeper embayments swamp facies survive from the Flandrian transgression. Today, marine deposition is confined to the mouths of the estuaries, commonly as barrier beaches and spits whose sands are washed and blown over into the lagoons. These barriers are periodically destroyed by discharging floodwaters but are soon rebuilt by powerful longshore currents. Older marine deposits, however, occur at depths beneath the larger estuaries, having been carried in by wave and tidal action during the Flandrian transgression. The largest estuaries experience a range of up to 20 m between the highest flood levels and the deepest scour troughs under present conditions.

OWEN, M. W. 1970a (Sep). "A Detailed Study of the Settling Velocities of an Estuary Mud," Report No. INT 78, Hydraulics Research Station, Wallingford, England.

Detailed tests on a mud, obtained from Avonmouth in the Severn estuary, were carried out in bottom withdrawal tubes up to 2.0 metres high to determine the effect of suspended concentration, salinity, and depth of settling on the sedimentation rate.

The settling velocity was found to increase with concentration up to about 14 g/ℓ, when hindered settling begins, and with salinity up to about 30 g/ℓ. Initially the settling velocity reduced with increasing depth, reaching a minimum value at about 1.0 metres, but it increased thereafter up to a depth of about 2.0 metres, when settling velocity became constant.

OWEN, M. W. 1976 (Oct). "Determination of the Settling Velocities of Cohesive Muds," Report No. IT 161, Hydraulics Research Station, Wallingford, England.

Standard methods used at the Hydraulic Research Station to measure the settling velocities of cohesive muds in the laboratory and in the field are described. Details are given of the apparatus required and of the experimental methods used. Worked examples are included to illustrate the calculation of the results.

OWEN, M. W. 1971. "The Effect of Turbulence on Settling Velocities of Silt Flocs," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, pp 27-32.

An instrument was developed to take undisturbed samples of suspended silt in an estuary and to determine the settling velocity of the silt flocs in their natural state. The instrument was used to carry out tests to determine the effect of turbulence on the settling velocity of the suspended flocs by sampling at various positions in an estuary during spring and neap tides. The results were compared with results of normal methods of sampling, with laboratory tests, and showed settling velocities up to ten times greater than either alternative method. The settling velocities were also found to vary linearly with suspended concentration during spring tides and with the square of concentration during neap tides. The differences were attributed to the difference in turbulent structures for the two extremes of tidal range.

OWEN, M. W. 1975 (Sep). "Erosion of Avonmouth Mud," Report No. INT 150, Hydraulics Research Station, Wallingford, England.

Tests were carried out in a re-circulating flume to study the erosion of mud beds naturally deposited from quiescent suspensions. Beds of Avonmouth mud at two different densities and salinities were examined. The results showed that the erosion process could be divided into two zones, depending on the applied shear stress. At shear stresses below a certain critical value, erosion occurred only until an equilibrium condition was established; at higher shear stresses erosion continued indefinitely, being limited only by the quantity of mud available.

The tests failed to establish conclusively what factors governed the state of equilibrium, although it appeared that erosion proceeded until a layer of the mud bed was exposed which was sufficiently strong to resist further erosion at the applied shear stress. Tests at different bed densities showed that a fixed proportion of the bed was eroded at equilibrium for a given shear stress and salinity, but tests at different salinities showed that less erosion occurred for mud beds at higher salinities.

At shear stresses above the critical value, the rate of erosion increased linearly with applied stress. Tests at different bed densities and salinities showed small differences in the values of the critical shear stress, but these were barely significant. However, the slope of the linear relationships differed substantially, with the rate of erosion being much less both for the beds of higher density and higher salinity.

OWEN, M. W. 1977. "Problems in the Modeling of Transport, Erosion, and Deposition of Cohesive Sediments," The Sea IV, Marine Modeling, E. D. Goldberg, I. N. McCave, J. J. O'Brien, and J. H. Steel, eds., Chapter 12, pp 515-537, Wiley-Interscience, New York.

Mathematical models of the transport, deposition, and erosion of cohesive sediments are still in their infancy, owing to our incomplete understanding of the basic processes of erosion, flocculation, deposition, consolidation, and vertical mixing in the flow. Nevertheless, surprisingly good agreement between model and natural conditions can be obtained with very simple models, even in estuaries where flow depths, velocities, suspended concentrations, and salinities all change significantly during the tidal cycle. Considerable additional research is necessary before mathematical models can be applied with absolute confidence to every situation where transport of cohesive sediments occurs.

OWEN, M. W. 1970b (Dec). "Properties of a Consolidating Mud," Report No. INT 83, Hydraulics Research Station, Wallingford, England.

Tests were carried out to determine the effect of suspended concentration, salinity, and bed thickness on the properties of mud beds formed by sedimentation in a 10-metre-high settling column. The various properties investigated included bed densities, surface sinking rates, and bed shear strengths.

Using Kynch's theory, density profiles within the beds were calculated from the bed thickness at intervals throughout formation and consolidation and were measured when the beds had consolidated for three days. The variations of shear strength and differential viscosity were also measured at this stage.

Varying the salinity was found to have virtually no effect on the bed properties of this particular mud. The test series at various concentrations and a similar series at various suspension depths showed that the bed properties depended only on the total amount of mud in suspension, irrespective of the concentration or water depth.

The mean density of the beds during formation was found to increase with suspended concentration, but the surface density decreased with increasing bed thickness. Shallow beds were also found to consolidate more rapidly and to have a higher surface shear strength than thick beds. The bed density variations were plotted on a dimensionless basis, and the measured values after three days' consolidation were found to lie on a common profile whatever the bed thickness. The shear strength measurements were found to correlate with the local bed density.

OWEN, M. W. 1966 (Nov). "A Study of the Properties and Behaviour of Muds," Report No. INT 61, Literature Review, Hydraulics Research Station, Wallingford, England.

This report is intended as a brief survey of the literature studied to date on the properties and behavior of cohesive muds. The reader is referred also to the summary by Partheniades of results of various research projects in this field.

For convenience, the literature currently summarized has been divided into two main categories, namely (a) deposition and consolidation and (b) erosion, but results of field work have not been included.

OWEN, M. W., and ODD, N. V. M. 1972. "A Mathematical Model of the Effect of a Tidal Barrier on Siltation in an Estuary," Tidal Power, T. J. Gray and O. K. Grashus, eds., pp 457-485, Plenum Press, New York.

The Greater London Council commissioned the Hydraulics Research Station to carry out a comprehensive investigation of the hydraulic aspects of means of preventing flooding in Central London. The mathematical model of silt movement in the Thames estuary described in this paper forms part of that investigation. The main purpose of the model was to attempt to reproduce the periodic pattern of suspended silt concentrations and the location of the main areas of deposition of silt in the estuary; hence, to test the effects of silt movement in the estuary of various tidal barriers proposed for flood protection.

As far as is known, this is the first time that such a model has been attempted, and further work is necessary before it can be accepted as completely reliable for investigating detailed changes in an estuary. In particular, fundamental research designed to give a better understanding of the processes of silt movement is continuing at the Hydraulics Research Station. Nevertheless, the study has given an overall indication of the changes which could result from various flood protection schemes involving tidal control.

OWENS, E. H. 1975 (Jun). "Barrier Beaches and Sediment Transport in the Southern Gulf of St. Lawrence," Coastal Engineering, 1974 Proceedings, American Society of Civil Engineers, Vol II, pp 1177-1193.

Barrier islands and barrier beaches have developed across structurally controlled estuaries and embayments in the southern Gulf of St. Lawrence. The supply of sediments to the littoral zone and the subsequent accumulation of barrier deposits is a result of the reworking, transportation, and longshore dispersal of sediments which are moved landward by tidal and wave-induced currents from the adjacent shallow sea floor. The size and stability of the barriers is controlled by the shoreline orientation.

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PARKER, W. R., and KIRBY, R. 1981a. "Defining Navigable Depth in Cohesive Sediment Areas," US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The maintenance dredging of mud is a very costly and notoriously inefficient and ineffective operation. The need for dredging, the quantity required, and how much is achieved depend in part upon the definition of navigable depth. In areas of mud sedimentation, there is frequently conflict, between the client requesting dredging and the contractor completing it, over how much dredging has, or has not, been achieved and must be paid for.

The origins of these problems lie in the criteria used to define navigable depth and the means used to locate the depth defined. The natural source lies in the behavior of fine sediment and the formation of fluff.

This report aims to review the available methods for locating navigable depth, their relationship to the physical properties of the materials concerned, and the criteria on which navigability is defined.

Examination of these areas leads to a new definition of navigable depth, the concept of NAUTICAL DEPTH, and defines the criteria on which it is based and the means for locating it.

A practical example is given of the application of these new concepts to the reduction of dredging in Europoort, the largest port in the world.

PARKER, W. R., and KIRBY, R. 1977 (Nov). "Fine Sediment Studies Relevant to Dredging Practice and Control," Second International Symposium on Dredging Technology, Paper B2, pp B2-13 - B1-26.

Fine sediment arrives as mobile suspensions at sites from which it must be dredged. In high turbid estuaries dense mobile suspensions are regularly produced as part of the natural circulation of fine sediment. In low turbidity estuaries their intermittent formation by storms, or during dredging and dumping operations, may be more important in relation to dredging problems.

The evolution of mobile suspensions into static suspensions, and their subsequent consolidation, cause time-dependent changes in density and acoustic properties which affect the nature of echosounder records from sites where static suspensions develop.

Field observations and laboratory studies indicate that, in areas of mud sedimentation, definitions of sea-bed altitude based only on echosounder records may be ambiguous unless the nature of what is acoustically identified is investigated by other means. The consequent problems of the definition of the sea bed may become acute in areas where the results of echosounding surveys are important for navigational purposes and for the specification and control of dredging operations.

The range of practical dredging problems encountered if the top reflector on an echosounder record is the only criterion used to define the sea bed, and the potential hazard of using lower reflectors without additional information, suggest that techniques for measuring in situ density, such as gamma-ray densimeters, are an essential supplement to echosounders.

PARKER, W. R., and KIRBY, R. 1982. "Time Dependent Properties of Cohesive Sediment Relevant to Sedimentation Management - European Experience," Estuarine Comparisons, V. S. Kennedy, ed., pp 573-589, Academic Press, New York.

Field observations show fine sediment suspensions often have a mobile, high-concentration layer adjacent to the sea bed. Stationary suspensions which have time-varying acoustic and mechanical properties develop from these layers. In these circumstances, conventional survey echosounders cannot provide unambiguous information on sea bed altitude relevant to safe navigation and optimum dredging practices. In Europe, echosounding is being replaced by in situ density measurement as the means to define navigable depth and to monitor or control dredging. Repeated in situ density surveys allow time series of mass deposition to be constructed, dredging schedules to be optimized, and productivity to be increased. Techniques may then be developed to trap sediment in designated sites where stationary pumping systems remove spoil automatically at an optimum density.

PARKER, W. R., and LEE, K. 1979 (Sep). "The Behaviour of Fine Sediment Relevant to the Dispersal of Pollutants," ICES Workshop on Sediment and Pollutant Interchange in Shallow Seas, Texel, England.

The processes of movement and the features of fine sediment behavior, relevant to the exchange of pollutants between sediment and water, are outlined.

Fine sediment suspensions tend to be stratified, particularly at high concentration. Stratification may be stable for long periods thus affecting mixing in those areas where it develops.

The relative motion of particles and water during large strain consolidation of soft sediment is shown to be capable of influencing developments of Eh within suspensions and deposited sediment and the return of porewater to the water column.

Attention is drawn to the effects of these processes in relation to the numerical modelling of pollutant dispersal by comparing the time frames of related processes.

AD-A188 349 FINE-GRAINED SEDIMENTS; AN ANNOTATED BIBLIOGRAPHY ON THEIR DYNAMIC BEHAVI..(U) ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS HYDRA.. 5/6

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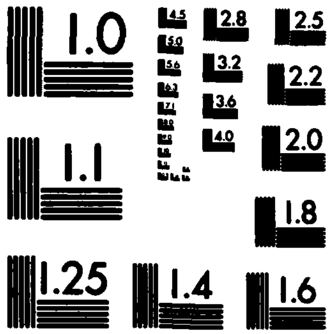

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PARKER, W. R., SILLS, G. C., and PASKE, R. E. A. 1975 (Sep). "In Situ Nuclear Density Measurements in Dredging Practice and Control," Paper B3, First International Symposium on Dredging Technology, pp B3-25 - B3-41.

Dredging practice and efficiency are influenced by sea bed density. In situ measurements of spoil density should be used in planning capital dredging programs, guiding and monitoring maintenance dredging, and quantifying descriptions of sea-bed altitude and its relevant changes.

Nuclear density gages have been used on land for some time but only recently in the marine environment. Differing requirements of spatial sampling and accuracy can be satisfied by using two types of nuclear densimeter, the backscatter probe or the transmission probe.

The laboratory performance of the backscatter probe has been examined and compared with the behavior predicted by a simple model. Some recommendations are made concerning applications of each probe, the interpretation of density structures and deployment criteria.

PARTHENIADES, E. 1965 (Jan). "Erosion and Deposition of Cohesive Soils," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 91, No. HY1, pp 105-139.

The main purposes of this study were to investigate the influence of shear stress, suspended cohesive sediment concentration, and shear strength of bed on the erosion rates of a cohesive bed in an open channel, and to study the deposition of suspended fine sediment at different velocities. It was found for the tested range of bed strength that the erosion rates were independent of the shear strength of the bed and of the concentration of suspended sediment, but that they depend strongly on the shear stress, increasing rapidly after a critical value of the shear stress had been reached.

The minimum shear stresses for the initiation of erosion were also found to be independent of the shear strength of the bed. At those shear stresses, all the clay part of the eroded material was held in suspension. This clay was rapidly deposited at velocities that were slightly smaller than the minimum scouring velocities.

A straight rectangular flume was used with recirculating water at ocean salinity. A special kind of clay commonly known as San Francisco bay mud was used as bed material. This clay is composed of approximately equal amounts of silt and clay, and it contains small amounts of fine sand. Two beds were tested. The first one was placed at field moisture, which was slightly higher than the liquid limit of the material. The second was a flocculated bed deposited in the flume directly from suspension.

The developed erosion patterns together with chemical and mechanical changes of the bed surface during the process of erosion and deposition have been carefully observed and described. In all cases, the main characteristic of erosion pattern was a well defined narrow and relatively straight zone of deep scouring. The rest of the bed surface was characterized by smooth and small ripples. Cementing agents dissolved in the water and suspended sand were found to cause significant changes in the properties of the bed surface.

PARTHENIADES, E. 1966 (Jun). "Field Investigations to Determine Sediment Sources and Salinity Intrusion in the Maracaibo Estuary, Venezuela," Report No. 94, Hydrodynamics Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

An extensive field investigation has been undertaken in the Lake Maracaibo estuary, Venezuela, to identify the sources of sediment being continuously deposited in the dredged channel connecting Lake Maracaibo and the Gulf of Venezuela, and to describe the mechanics responsible for the transport of the deposited sediment and the observed increase in the salinity of the lake. The investigation is based primarily on field measurements of the spacial and temporal distributions of suspended sediment concentrations, salinity, and velocity.

The results of the investigation indicate that the bulk of sediment causing the shoaling comes from the Gulf of Venezuela, where it originates from coastal erosion, strong littoral transport of sand, and resuspension of fine material by wave action. This sediment is subsequently transported toward the lake by an upstream underflow of saline water near the bottom of the channel and is deposited in certain regions along the channel, causing the observed shoaling. Relatively high sediment concentration is encountered only near the bottom of the channel and well within the saline underflow, whereas the upper less saline water is practically free of sediment. Very little suspended sediment was encountered in the shallow zones adjacent to the navigation channel.

The salinity data were analyzed by a one-dimensional method based on a mass transfer theory. The longitudinal salinity distribution at lower water slack was compared with a theoretical model and two independent parameters characterizing the longitudinal salinity distribution were determined. These parameters are the apparent diffusion coefficient D_o' and a characteristic length B. Previous investigations indicated that a correlation exists between a dimensionless form of these parameters and a dimensionless stratification number for the estuary.

The stratification number depends on the tidal prism, the tidal velocity, the mean water depth, the fresh water discharge, and the tidal period. It has been shown that the salinity data of the Maracaibo estuary agree with the expected correlations. Certain assumptions were necessary about the freshwater discharge from the lake to the gulf. On the basis of the obtained correlations it is possible to predict changes in the salinity distribution caused by changes in the hydraulic and tidal regime. Changes in the salinity distribution caused by future remedial operations such as the construction of parallel dikes in the Tablazo Bay are discussed.

PARTHENIADES, E. 1962. "A Study of Erosion and Deposition of Cohesive Soils in Salt Water," Ph.D. Dissertation, University of California, Berkeley, Calif.

The main purposes of this dissertation were: (a) to investigate the influence of shear stress, suspended cohesive sediment concentration, and shear strength of bed on the erosion rates of a cohesive bed in an open channel and (b) to study the deposition of suspended sediment at different velocities. It was found that for the tested range of bed strength the erosion rates were independent of the shear strength of the bed and of the concentration of suspended sediment, but that they depend strongly on the shear stress increasing very rapidly after a critical value of the shear stress had been reached. The minimum shear stresses for initiation of erosion were also found to be independent of the shear strength of the bed. At those shear stresses all the clay portion of the eroded material was held in suspension. This clay was rapidly deposited at velocities which were slightly smaller than the minimum scouring velocities.

A straight rectangular flume was used with recirculating water at ocean salinity. A special kind of clay commonly known as San Francisco bay mud was used as bed material. This clay is composed of about equal amounts of silt and clay and it contains small amounts of fine sand. Two beds were tested. The first one was placed at field moisture, which was slightly higher than the liquid limit of the material. The second was a flocculated bed deposited in the flume directly from suspension.

The developed erosion patterns together with chemical and mechanical changes of the bed surface during the process of erosion and deposition have been carefully observed and described. In all cases the main characteristic of erosion patterns was a well defined narrow and relatively straight zone of deep scouring with very little meandering. The rest of the bed surface was characterized by very smooth and small ripples. Cementing agents dissolved in the water and suspended sand were found to cause significant changes in the properties of the bed surface.

PARTHENIADES, E. 1977 (Sep). "Unified View of Wash Load and Bed Material Load," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 103, No. HY9, pp 1037-1057.

This paper presents a new generalized model of flow-sediment interaction. The behavior of the wash load and of the suspended bed-material load can then result as special cases of the new model. The latter follows the lines of Einstein's original probabilistic model except that interparticle forces of mechanical and physico-chemical nature have been introduced and that the flow-induced forces on the individual grains or flocs were assumed to have an upper and lower bound. It is shown that the actual wash load may consist of two distinct types of sediment which may coexist: (a) bed load function for a limited range of flow conditions whereas above that range it behaves as a wash load, and (b) the other never has a bed-load function. It is shown that the latter consists predominantly of silt and clay, i.e., of sediment finer than 0.06 mm, a fact consistently observed in alluvial channels.

PARTHENIADES, E., and KENNEDY, J. F. 1966 (Sep). "Depositional Behavior of Fine Sediment in a Turbulent Fluid Motion," Proceedings, Tenth Conference on Coastal Engineering, American Society of Civil Engineers, Vol II, Chapter 41, pp 707-729.

An experimental investigation, utilizing an apparatus consisting of a counter-rotating annular channel and ring, of the depositional characteristics of fine, cohesive sediment revealed that, after an initial period of rapid deposition, the sediment concentration approaches asymptotically an equilibrium value. The ratio of this equilibrium concentration to the initial concentration is nearly independent of initial concentration and for a given sediment and environment depends only on the flow conditions. For the three water depths investigated, the ratio of equilibrium to initial concentration was found to be a single function of an average shear stress around the channel-section perimeter. A comparison of the size distributions of the parent material with the material retained in suspension when equilibrium was achieved indicated that the greatest losses occur in the clay-size fractions, suggesting that the deposition is controlled predominantly by flocculation, and that the strength and size of the flocs exert a stronger influence on the deposition than does the particle weight. A silty-clay sediment with a mean particle diameter of 0.0009 mm was used in all experiments.

PARTHENIADES, E., and MEHTA, A. J. 1971. "Rates of Deposition of Fine Cohesive Sediments in Turbulent Flows," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, pp 17-26.

Experimental results of a basic investigation of the role of flow parameters on the deposition of fine cohesive sediments are herewith presented. The study utilizes a special apparatus consisting of a system of rotating annular channel and ring. The current studies have confirmed earlier conclusions that the percentage of the total sediment that a given flow can maintain in suspension depends only on the bed shear stress and is independent of the initial sediment concentration. The percentage C', of the depositable sediment deposited at time t has been found to vary with time according to the law $C' = \alpha \log t - \beta$, where α appears to be independent of the flow conditions and sediment concentration, while β is a function of the bed shear stress only. Both α and β are expected to depend on the physico-chemical properties of the sediment and the water environment. It follows that the deposition rates are proportional to the depositable sediment concentration and inversely proportional to time.

PARTHENIADES, E., CROSS, R. H., III, and AYORA, A. 1968. "Further Results on the Deposition of Cohesive Sediments," Proceedings, Eleventh Conference on Coastal Engineering, Chapter 47, pp 723-742.

Experimental investigations on the depositional behavior of suspensions of fine cohesive sediments in turbulent flows have been conducted in a special laboratory apparatus. This apparatus consists essentially of an annular channel containing the water-sediment mixture and an annular ring positioned within the channel and in contact with the water surface. A turbulent shear flow is generated by a simultaneous rotation of the channel and ring in opposite directions at the proper relative speeds to minimize secondary currents in the bottom of the channel, so that the sediment deposits uniformly.

PARTHENIADES, E., KENNEDY, J. F., ETTER, R. J., and HOYER, R. P. 1966 (Jun). "Investigations of the Depositional Behavior of Fine Cohesive Sediments in an Annular Rotating Channel," Report No. 96, Hydrodynamics Laboratory, Massachusetts Institute of Technology, Cambridge, Mass.

The depositional behavior of fine cohesive sediments, of the silt and clay types, is an important factor in the control of shoaling and the economical maintenance of estuarial channels. Fine cohesive substances are subject to flocculation caused by the interparticle attractive physicochemical forces. Flocculation results in the formation of agglomerations of individual particles, called "flocs," which may deposit quite rapidly. The floc size distribution depends on both the soil properties and the flow conditions. The purpose of the present study is to investigate the important flow parameters and soil properties which control the depositional behavior of fine sediments. It is part of a major research project at MIT, whose purpose is to determine the interaction of tides, salinity, sediment, and freshwater discharge in the Lake Maracaibo navigation channel in Venezuela, where heavy shoaling occurs due to the deposition of predominantly fine sediment.

The special apparatus in which the experiments were conducted consists of a rotating annular channel, with outer and inner diameters of 36 and 28-3/8 inches, respectively, and a counter-rotating annular ring positioned to be in contact with the fluid. The counter-rotation of the tank and ring produces an effectively endless turbulent flow field. This apparatus does not have any floc-disrupting elements. The depths of flow and the speeds of rotation for the ring and channel can be varied over a wide range and the system is instrumented to measure the shear stresses on the ring. Moreover, the speeds of rotation can be adjusted so that the effect of secondary currents is minimized and the sediment deposits uniformly across the channel.

PEARSON, H. J., VALIOULIS, I. A., and LIST, E. J. .984 (Jun). "Monte Carlo Simulation of Coagulation in Discrete Particle-Size Distributions, Part I. Brownian Motion and Fluid Shearing," Journal of Fluid Mechanics, Vol 143, pp 367-385.

A method for the Monte Carlo simulation, by digital computer, of the evolution of a colliding and coagulating population of suspended particles is described. Collision mechanisms studied both separately and in combination are: Brownian motion of the particles, and laminar and isotropic turbulent shearing motions of the suspending fluid. Steady-state distributions are obtained by adding unit-size particles at a constant rate and removing all particles once they reach a preset maximum volume. The resulting size distributions are found to agree with these obtained by dimensional analysis.

PEIRCE, T. J., and WILLIAMS, D. J. 1966. "Experiments on Certain Aspects of Sedimentation of Estuarine Muds," Proceedings, The Institution of Civil Engineers, Vol 34, Paper No. 6931, pp 391-402.

Estuarine muds in suspension have been shown to exist as flocs, consisting of groups of solid particles with occluded water. From an analysis of the variation of sedimentation velocity with solids concentration, the average floc density and diameter were estimated. The materials could be deflocculated by reducing the salinity of the suspension medium. The muds, when permitted to settle, compacted under their own weights to different extents.

PEIRCE, T. J., JARMAN, R. T., and DeTURVILLE, C. M. 1970 (Feb). "An Experimental Study of Silt Scouring," Proceedings, The Institute of Civil Engineers, Vol 45, pp 231-243.

Laboratory and field measurements of the hydraulic shear needed to scour estuarine muds have been made at coastal and estuarine sites. A small portable flume was designed and used to compare the erosion of muds in their natural environment with similar mud samples reconstituted in the laboratory. The results of field tests were shown to be reasonably reproducible in the laboratory. Muds from different sources were found to scour at different rates. Laboratory measurements in a small flume showed that the fluid shear needed to erode reconstituted estuary mud ranged from 16 dyns/cm^2 for Bromborough mud to approximately 160 dyns/cm^2 for Hayle mud. The bed material was eroded in the form of aggregates whose size was characteristic of the place of origin of the mud. Some of the properties of sediments which could have caused their erodibility to differ have been measured and are briefly reported.

PETERSON, D. H., CONOMOS, T. J., BROENKOW, W. W., and DOHERTY, P. C. 1975. "Location of the Non-Tidal Current Null Zone in Northern San Francisco Bay," Estuarine and Coastal Marine Science, Vol 3, pp 1-9.

Variations in Sacramento-San Joaquin River discharge into northern San Francisco Bay causes shifts in location of the bottom density current null zone. At a river flow of 2,000 m^3/s this null zone is approximately 20 km from the seaward end of the estuary, whereas at a river flow of 100 m^3/s it is 80 km from the seaward end; the corresponding distances of salinity penetration are approximately 40 and 90 km from the seaward end. Seaward of the null zone, during low (summer) river discharge conditions, the inward-flowing bottom density current appears typically strong (5 to 15 cm/s) relative to the outward-flowing river current (river discharge per unit cross-channel area) of <2 cm/s. Landward from this null zone the average river current increases with decreasing cross-channel area. This circulation implies that during the summer water within the null zone has the longest average advective replacement time relative to water seaward or landward of the null zone.

PETERSON, J. C. 1971 (Mar). "Water Content Determinations for Dried Marine Sediments," M.S. Thesis, United States Naval Postgraduate School, Monterey, Calif.

A quantitative analysis of residual salts in dried marine sediments was accomplished by reconstituting the sediment with distilled water and measuring the salinity of the resulting solution. The information obtained from these measurements provided an excellent basis for predicting the water content of the original unaltered samples. With the original salinity of the interstitial water known, the water contents computed from the salt content determinations were, for all practical purposes, as accurate as the original water contents.

PICOLOGLOU, B. F., ZELVER, N., and CHARACKLIS, W. G. 1980 (May). "Biofilm Growth and Hydraulic Performance," Journal, Hydraulic Division, American Society of Civil Engineers, Vol 106, No. HY5, pp 733-746.

Biofouling in water conduits causes pronounced increases in fluid frictional resistance. The resulting energy losses are of major concern to the water-supply and power industries.

Biofouling is a general term referring to undesirable effects due to attachment of microorganisms at liquid-solid interfaces. The microorganisms produce a polysaccharide slime layer that, when formed on the inside surface of water conduits, increases frictional resistance in flow systems resulting in energy losses or losses in pipeline capacity.

Biofouling is not limited to microbial activity. The term includes the interaction of the microorganisms and the slime layer with both the chemistry of the solid surface and the bulk fluid. These interactions can enhance some of the more commonly known fouling phenomena such as precipitation or crystallization (scaling) and corrosion. In these latter cases, the wall layer attains a much more rigid structure and the pronounced increase in frictional resistance can be successfully explained by the increase in the equivalent sand roughness of the pipe wall. In the case of microbial slime layers, the situation is more complex. The thickness and morphology of the slime layers are functions of the operating conditions. A change in operating conditions, such as an increase in wall shear stress, can cause significant changes in the morphology and thickness of the biofilm, thus changing the value of the equivalent sand roughness. In addition, the viscoelastic nature of the slime layer and its filamentous morphology suggest that perhaps additional dissipation mechanisms contribute significantly to the increased frictional resistance. Consequently, description of the biofilm effect by a unique value of equivalent sand roughness may be inadequate over the entire range of the operating conditions.

The purpose of this study is to explore some of these possibilities. This paper will only be concerned with microbial slime layers and, therefore, the term biofouling will be used for microbial fouling and the term biofilm for the microbial slime layer.

PINSAK, A. P., and MURRAY, H. H. 1958 (Oct). "Regional Clay Mineral Patterns in the Gulf of Mexico," Clays and Clay Minerals, Proceedings of the Seventh National Conference on Clays and Clay Minerals, pp 162-177.

A semiquantitative study of the surficial clay mineral distribution from 79 cores in the Recent sediments in the Gulf of Mexico shows a regional pattern which can be related to source and environment. The dominant factor controlling distribution of these surficial sediments appears to be source. Montmorillonite is the most abundant clay mineral, and illite, chlorite, kaolinite, and mixed-layer minerals are present in almost every sample.

Alteration of the clay minerals is influenced by (a) change of environment and (b) length of exposure. Initial ion exchange, which is caused by a tendency to reach equilibrium with a new environment, occurs so rapidly in the clay minerals after they enter the marine environment that rate of sedimentation is a minor factor in comparison to environmental change. Slow alteration and adjustment toward a stable end state are most complete in areas of slow deposition and extended exposure of the clay minerals to the environment.

PIPER, D. J. W. 1978. "Turbidite Muds and Silts on Deepsea Fans and Abyssal Plains," Sedimentation in Submarine Canyons, Fans, and Trenches, D. J. Stanley and G. Kelling, eds., Chapter 12, pp 163-176, Dowden, Hutchinson and Ross, Inc., Stroudsburg, Penn.

Silts and muds deposited by turbidity currents are a major component of deepsea terrigenous sediment sequences. Mud turbidites have three divisions that are analogous to Bouma's divisions for sand turbidites: laminated mud, graded mud, and ungraded mud. Disorganized laminated muds are most common on levees and graded muds in deepsea fan valleys; ungraded muds predominate in distal environments. Floc breakup and reformation in a turbidity current results in a progressive segregation of silt and clay, so that sorted silt beds are characteristic of distal environments. Three types of turbidite silt are distinguished. The deposits of contour currents and lutite flows may often resemble mud turbidites, and there is no simple set of criteria to distinguish them.

POINDEXTER, M. E. 1984 (Nov). "Techniques for Long-Term Management of Confined Disposal Areas," Proceedings, Dredging Conference, American Society of Civil Engineers, pp 886-895.

Systematic management of confined dredged material disposal sites is becoming increasingly necessary as competition for land use intensifies in regions in which most dredging projects are located. Long-term management of either single or multiple disposal sites entails determination of the storage capacity required to contain the sediments to be dredged over a period of years. Techniques for constructive management of confined disposal sites have been developed at the US Army Engineer Waterways Experiment Station.

The purpose of this paper is to present techniques to be utilized in long-term management of confined dredged material disposal areas. The large strain consolidation behavior of dredged material and use of an available finite strain mathematical model are discussed. Recommendations will be made concerning operation of the disposal site(s) to maximize potential service life or available storage capacity.

POSTMA, H. 1967a. "Marine Pollution and Sedimentology," Conference on the Status of Knowledge, Critical Research Needs, and Potential Research Facilities Relating to Ecology and Pollution Problems in the Marine Environment, T. A. Oldon and F. J. Burgess, eds., pp 225-234.

Solid wastes introduced in suspended form into natural water will show a behavior similar to that of natural sediments. The same applies to dissolved waste products which are absorbed by particulate matter. Our growing knowledge of marine sedimentological and geochemical processes may, therefore, be of some assistance in studying the behavior of wastes in the sea. Also it must be possible, in principle, to use certain forms of suspended waste as tracers in the study of sediment transport.

Obviously, a large number of sedimentary processes could be mentioned which, in some way or other, might be valuable for an understanding of the fate of contaminants. In addition, a wide range of waste products could be discussed, each of which could behave in a different manner. Generally speaking, each separate plan for waste disposal will need a research program attuned to local conditions. A discussion of specific research programs would go far beyond the scope of this paper. Instead, emphasis will therefore be placed on some general aspects of the transportation, the concentration, and the deposition of suspended matter in nearshore waters, which may be of value to understand the transport of suspended water.

POSTMA, H. 1967b. "Sediment Transport and Sedimentation in the Estuarine Environment," Estuaries, G. H. Lauff, ed., Publication No. 83, pp 158-179, American Association for the Advancement of Science, Washington, DC.

A review of sediment movement in nearshore waters, tidal flat areas, and estuaries shows that various transport mechanisms may be active which tend to hold the material within these regions. Loss to offshore and deep waters seems to be less than one should expect from the rates of coastal water removal and the concentration gradients of suspended sediments from the shores to the sea. Among the accumulation mechanisms holding suspended matter near the coast are settling and scour lag effects, which, in combination with tidal movements, can lead to residual transport towards the coast. Density differences, especially those occurring in and near rivers owing to freshwater runoff, may result in the concentration of suspended materials in turbidity maxima.

The sizes of the particles which are efficiently retained depend on local conditions and on the type of accumulation process, but the retention is usually most effective for fine-grained matter. A grain size of about 100 μ may tentatively be considered as the upper limit, the lower limit may be as low as 5 to 10 μ. These values refer to equivalent grain sizes. Retention and sedimentation of fine-grained matter are promoted by flocculation. Scour lag effects are increased if the material is given time to consolidate.

The confinement of suspended matter within a certain region, combined with movement by tidal and density currents, has an important selective effect on the grain-size distribution of the deposits. In many areas the distributional patterns are closely related to water movements, including that of waves. However, the grain size and the concentrations of the suspended matter present are also important. Deeper waters offshore are often sufficiently quiet for mud deposition, but the deposits are coarse since no fine-grained suspended matter is available. Conversely, muddy deposits may be formed in rough water if sufficient fine-grained materials are supplied.

POTTER, P. E., HELING, D., SHIMP, N. F., and WIE, W. V. 1975. "Clay Mineralogy of Modern Alluvial Muds of the Mississippi River Basin," Bulletin of the Center for Research, Vol 9, No. 2, pp 353-389.

Modern alluvial muds from the Mississippi River Basin, which covers 1,243,000 square miles (3,220,900 km^2), belong to two major mineralogical associations: (a) a smectite association extending eastward from the Rocky Mountains to Indiana and (b) an eastern illite-chlorite-kaolinite association. The western association is associated with lower rainfall and Cretaceous-Tertiary sediments, whereas the eastern one is associated with higher rainfall and middle and lower Paleozoic sediments. Glaciation and widespread loess deposition during the Pleistocene extended the distribution of smectite eastward. In the southwestern part of the basin, in the Arkansas and Red River drainage area, both associations are present, although the smectite association predominates. Data from 177 samples were used in the study.

Both our study and previous ones suggest that alluvial muds very largely reflect source rocks rather than either climate or relief in all basins excepts those of low relief in tropical climates.

PRICE, W. A., and KENDRICK, A. M. P. 1981. "Dredging and Siltation--Cause and Effect," Institute of Civil Engineers Symposium on Dredging, Paper 4, pp 31-36.

The paper questions the thesis: the greater the dredging activity, the better the depths. Experiments on a hydraulic scale model with a movable bed suggested that, where large-scale dredging was being carried out, big reductions in dredging rates could lead to improved depths. Subsequent events in nature confirmed the model findings and indicated that the dredging method was also important, the amount of material that has to be removed to obtain a given depth varying with the type of dredger employed. The serious consequences of overdredging are discussed, and the factors influencing the selection of a deposit ground are enumerated. The paper concludes with a critical review of the contribution that hydraulic model investigations can help towards making a better quantitative assessment of future dredging requirements.

PRICE, W. A., and KENDRICK, M. P. 1963. "Field and Model Investigation into the Reasons for Siltation in the Mersey Estuary," Proceedings, Institute of Civil Engineers, Paper No. 6669, pp 473-517.

The paper gives an account of an investigation carried out by the Hydraulics Research Station, Wallingford, into the reasons for siltation in the estuary of the River Mersey. A short description of the estuary and its tidal characteristics is followed by a statement of the main problems and an account of the methods adopted in tackling them--field work, a historical chart analysis, and scale model tests.

The source of the material contributing to upper estuary siltation being Liverpool Bay, there follows a discussion of prototype observations of currents, salinities, and concentrations of suspended solids establishing the existence of a net landward drift of water near the bed of the estuary which carries sand upstream. The importance of salinity/density currents in a well-mixed estuary is emphasized, confirmation being provided by experiments on a large tidal model with a movable bed in which the natural salinity distribution was reproduced.

A second tidal model showed how the construction of training walls in Liverpool Bay had altered the circulation pattern thereby increasing the supply of material arriving at the mouth, and a field experiment using radioactive tracers confirmed the view that dredged material should be dumped where it will not return to the estuary. A study of the upper estuary established that there has been some restriction in the movement of the low-water channel above Eastham--a further factor likely to have contributed to upper estuary siltation.

After a discussion of the general problem of the falling capacity of the estuary, attention is directed to the more immediate, local problems associated with shoaling in the Eastham and Garston channels.

Finally, tests on training schemes in the Eastham channel indicated how depths over Bromborough Bar might be increased, and a preliminary examination into the possibility of improving conditions in both the Eastham and Garston channels by the construction of an island in the wide part of the upper estuary showed the scheme to be unrealistic from a hydraulic point of view.

PYSHKIN, B. A. 1973 (Jul-Aug). "Investigations of the Protection of Ports and Water Intakes from Obstruction by the Accumulation of Sediment from the Windward Side of the Installation," Fluid Mechanics, Vol 2, No. 4, pp 5-11.

The results of experimental and full-scale studies on the protection of ports and coastal water intakes and water reservoirs from sediment accumulation from the windward side of structures by a single mole, a system of jetties and sediment-traps are discussed. An approximation method for calculating the capacity of sediment-traps and the time taken to fill them with sediment is presented.

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RASMUSSEN, J. F. 1972 (Oct). "Sedimentation Effects of Hydroelectric Development," Journal, Power Division, American Society of Civil Engineers, Vol 98, No. PO2, pp 313-321.

First of all, the basic problem that exists is the freshwater-saltwater density current affecting a sediment trap and of course the sediment load all caused by diversion of Santee River into Cooper River. Second, the solution to the problem is rediversion of the sediment-laden freshwater. Third, there are two methods to accomplish this solution effectively. The hydro-replacement plan is the best suited. Fourth, the solution will not become operational until about 1978. And fifth, the solution to the problem shall not create new problem areas as a by-product, for the water will be returned nearly undiminished and unimpaired to the waterway nature intended.

Although technology eventually gained forward direction due to the placement of a dam diverting the Santee River, it was at the expense of complete change of regimen within two stable ecosystems and has caused millions of dollars to be expended in maintenance dredging. The conclusions seem apparent. In the development of any resource, particularly hydroelectric generation, all aspects existing within the affected system should be fully investigated. It will be difficult (just as it was in 1941) to predetermine effects of phenomena not fully understood. Development should be born out of desire to progress rather than corrective necessity.

REINECK, H. E.. 1975. "German North Sea Tidal Flats," Tidal Deposits, R. N. Ginsburg, ed., Chapter 1, pp 5-12, Springer-Verlag, New York.

Subtidal channels are cut in older sediments. Subtidal deposits are mainly channel and shoal deposits. Channel deposits are characterized by discordances. Even the intertidal zone shows abundant channel deposits with erosional disconformities. The deposits often show strong bioturbation and horizons of molluskan shells in living position. Alternating bedding is abundant, that is, flaser and lenticular bedding, thinly alternating sand-mud layers, and thickly alternating sand-mud layers. Surface markings indicating subaerial exposure is present. Sediments of the supratidal zone are distorted by roots, and bedding is uneven.

REINECK, H. E. 1967. "Layered Sediments on Tidal Flats, Beaches, and Shelf Bottoms of the North Sea," Estuaries, G. H. Lauff, ed., Publication No. 80, pp 191-206, American Association for the Advancement of Science, Washington, DC.

Sedimentary deposits of the past are frequently described on the basis of layers, banks, burrows, and other features of their structure; by grain size, mineral composition, and other characteristics indicative of the nature of the sediment; and by fossil content. These qualities are interpreted in relation to the environment of the deposition. The structures of sedimentary deposits often receive limited treatment by marine geologists because of technical difficulties. On the other hand, marine geologists are able to make observations which are helpful in interpreting the nature of fossil deposits. This paper approaches the study of sedimentary structures through use of a special apparatus, the grabsampler and other new methods of preparing the probes, or corers.

REINSON, G. E. 1977 (Nov). "Tidal-Current Control of Submarine Morphology at the Mouth of the Miramichi Estuary, New Brunswick," Canadian Journal of Earth Sciences, Vol 14, No. 11, pp 2524-2532.

The mouth of the microtidal Miramichi estuary, New Brunswick, is enclosed by a barrier-island system which is cut by two major tidal inlets. The submarine morphology adjacent to these inlets indicates the presence of large tidal deltas which formed predominantly by tidal-current processes. The extensive shoal water on the landward side of the barrier is due to the landward transport of sand through the inlets and the deposition of this sand as coalescing flood-tidal delta deposits. The creation of an artificial channel inside the main inlet in the late 19th century and its maintenance since that time have resulted in substantial channel-flow bypassing of the natural channel seaward of the barrier. This promoted the scouring of a new channel through the ebb-tidal delta shoal.

Large tidal deltas apparently are not common morphological features of estuaries on microtidal, barrier-island coastlines, but they do occur at the entrances of very large microtidal estuaries such as the Miramichi. In such cases they are usually completely subtidal, and much larger than tidal deltas of mesotidal estuaries reported in the literature. Rather than tidal range, the tidal prism, which takes into account both tidal range and estuary surface area, may play the major role in the formation of tidal deltas in both mesotidal and microtidal estuaries.

RHOADS, D. C. 1976 (Nov). "Containment Spoiling in Central Long Island Sound: An Example of Short-Term Biological Enhancement," Proceedings, Second Annual Conference, The Coastal Society, pp 56-69, New Orleans, La.

Nineteen active spoiling sites located in Long Island Sound regularly receive dredge spoils from harbor maintenance projects principally from the Connecticut coast. Over 1-1/2 million cubic yards of spoil are dumped at these 19 sites each year. Most spoiling is confined to water depths greater than 60 feet, 2-1/2 to 5 nautical miles from the Connecticut coast.

The New Haven spoiling ground is the best studied in Long Island Sound. Yale University and University of Connecticut researchers have studied the biological effects of a 1-million-cubic-yard dump at a containment site south of New Haven, Connecticut. This study, initiated in 1972, continues to the present time.

Since April 1974 (cessation of dumping at the New Haven site), the number of bottom-dwelling species and their population densities are 2 to 3 times higher on the dump site relative to the ambient seafloor. Few species are common to both the dump ground and the ambient seafloor. The observed biological enhancement was predicted on the basis of earlier field experiments and ecologic theory.

A short-term increase in bottom productivity on a spoiling ground (or any physically disturbed bottom) is expected where the spoils are relatively clean. Dredging procedures can be designed, in many cases, to insure a clean dump surface for larval settlement and colonization.

A preliminary dredging policy has been drafted by the State of Connecticut on the basis of the New Haven dump-site research and from data available from other well-studied dump operations.

RICHARDS, A. F., and KELLER, G. H. 1961 (May). "A Plastic-Barrel Sediment Corer," Instrumental Notes, pp 306-312.

A program was initiated by the US Hydrographic Office in 1958 to investigate engineering and mass physical properties of marine sediments. Conventional gravity- and piston-type corers using small-diameter metal barrels with or without plastic core liners were found unsatisfactory for use in this program: metal barrels easily rusted and were difficult to section into short lengths for vane shear strength tests of the core within the barrel and cellulose acetate butyrate core liners readily lost water if not protected from desiccation. Neither the Ewing- nor Kullenberg-type corers in use by the Hydrographic Office obtained cores with diameters large enough to provide sufficient material for certain laboratory tests made occasionally on very short, 1-cm, samples.

Consultation with plastics experts in the Office of Naval Research and Naval Ordnance Laboratory indicated that two readily available plastic pipes, polyvinyl chloride (PVC) and filament-wound epoxy resin fiberglass, might prove satisfactory for use as core barrels. Both were tried at sea and functioned well; however, because epoxy resin of the fiberglass pipe cracked and chipped if roughly handled, further development was confined to PVC pipe.

RICHARDSON, J. F., and ZAKI, W. N. 1954. "The Sedimentation of a Suspension of Uniform Spheres Under Conditions of Viscous Flow," Chemical Engineering Sciences, Vol 3, pp 65-73.

The dynamic equilibrium of a suspension of uniform spherical particles settling in a fluid has been considered, and an expression has been obtained for the drag force on a constituent particle. This has been expressed in the form of a correction factor to be used in conjunction with Stokes' Law and has been compared with the correction factor obtained from experimental measurement. Two configurations of particles have been considered and good agreement has been obtained between the theoretical and experimental correction factors at volumetric concentrations greater than about 0.05, though the correction factor extrapolates to zero, corresponding to zero drag on the particle, at infinite dilution. The reasons for this discrepancy are discussed.

RIEKE, H. H., III, and CHILINGARIAN, G. V. 1974a. "Effect of Compaction on Some Properties of Argillaceous Sediments," Developments in Sedimentology 16, Compaction of Argillaceous Sediments, Chapter 4, pp 147-148, 155-156, Elsevier Scientific Publishing Company, New York.

Sediment constituents exist in three physical states: solid, liquid, and gas. The solid phase is represented by minerals and organic materials, the liquid phase by brines and hydrocarbons, and the gaseous phase by natural gases and air. The variability of these three states gives rise to nonuniformity of argillaceous sediments and variation in their characteristics and properties. In addition to the nonhomogeneity, specific interactions among the three phases may occur during compaction. Thus, it is difficult to predict precisely the response of the sediment to a set of external constraints.

Sediment is composed of minerals of various grain sizes with some organic molecules strongly bonded to the minerals and some physically admixed organic matter. The arrangement of the mineral particles influences the properties of the sediment upon compaction. Yet, many physical measurements are made on argillaceous sediment samples that are remolded or disturbed, i.e., not in their natural state. Consequently, when the results of these tests are evaluated, it should be remembered that the in-situ arrangement of particles in the sediment has a definite effect on properties. Particle-size analysis only gives the proportion of different-sized particles present and not their arrangement with respect to each other.

RIEKE, H. H., III, and CHILINGARIAN, G. V. 1974b. "Interrelationships Among Density, Porosity, Remaining Moisture Content, Pressure and Depth," Developments in Sedimentology 16, Compaction of Argillaceous Sediments, Chapter 2, pp 31-80, Elsevier Scientific Publishing Company, New York.

This chapter is concerned primarily with the interrelationships among density, porosity, depth, and overburden pressure. Experimental data on the relationship between the remaining interstitial fluid content and applied pressure are also presented. According to Strakhov, the rapid escape of water from semiconsolidated clays occurs at depths down to 250 to 300 m. With continued subsidence, sediments become consolidated rocks and there is only a very slow escape of water and further compaction.

Muller pointed out that, once a certain overburden load has been reached and sediment is compacted, the process is irreversible; that is, even after a later uplift and erosion of the upper layers, with consequent release of pressure, the porosity attained at the maximum burial depth does not change subsequently. Thus, the maximum depth of burial experienced by the argillaceous sediment can be estimated from the porosity of unweathered rocks.

It has been shown by Chilingar and Knight that at any particular high overburden pressure the fluid content of a laboratory compacted clay is related to the type of clay mineral present. In recent years a great deal of new data have been accumulated on the compaction of muds, especially owing to the encounter of the petroleum industry with abnormally high fluid pressures in deeply buried shale sequences. Some of these data are presented here.

RIEKE, H. H., III, and CHILINGARIAN, G. V. 1974c. "Mechanics of Compaction, Interstitial Fluids, Abnormal Fluid Pressures," Developments in Sedimentology 16, Compaction of Argillaceous Sediments, Chapter 1, pp 11-12, 19-20, 23-24, Elsevier Scientific Publishing Company, New York.

Compaction of sediments under the influence of their own weight has long been a known geologic phenomenon. As pointed by Hedberg, in the seventeenth century Steno recognized that variations in the attitude of sedimentary strata might be due to compaction. In his excellent paper entitled "The application of quantitative methods to the study of the structure and history of rocks," Sorby presented original data on the porosity of natural sediments, discerned an inverse relationship between porosity and age, and recognized that the compaction of sediments is primarily a change in porosity. The structural effects of compaction were mentioned by Shaw and Munn, whereas the idea that the compaction of sediments may have played a part in the origin of oilfield structures has been championed by McCoy, Shaw, and Mehl. In 1926, Hedberg attempted a quantitative evaluation of the compaction of sediments. His work aroused great interest and inspired further research on the subject. Nevin presented an excellent discussion of geologic information on the compaction of sediments available up to 1931. Early geologic explanations on the settling of sediments and on the gravitational and other compaction theories have been presented by Blackwelder, Monnett, Lahee, Teas, Terzaghi, Hedberg, and Athy. Gravitational compaction is defined as the expulsion of pore fluids and the pore volume decreased in a sedimentary column as a result of normal and shear-compressional stresses due to the overburden load. Differential compaction refers to the gravitational compaction of sediments over and around a positive buried geomorphological feature such as a hill or a reef. The compaction of argillaceous sediments is treated in the present book, whereas the compaction of coarse-grained sediments is to be presented in a forthcoming volume of the series Developments in Sedimentology.

RIEKE, H. H., III, and CHILINGARIAN, G. V. 1974d. "Mechanics of Compaction and Compaction Models," Developments in Sedimentology 16, Compaction of Argillaceous Sediments, Chapter 3, pp 93-94, Elsevier Scientific Publishing Company, New York.

Until recently, sedimentologists did not pay much attention to the stresses in thick sedimentary sequences. Knowledge of the vertical and lateral stress patterns in a depositional basin is of the utmost importance, and a detailed investigation of the stress state in a basin may aid in anticipating the location of structures favorable for hydrocarbon entrapment. The history and development of depositional basins and the expulsion of interstitial fluids during basin subsidence should be better understood. For a more thorough quantitative understanding of compaction mechanics, the relationship between the total overburden stress, effective stress, and pore stress (pressure) in fine-grained clastics is analyzed in this chapter.

A study of the published literature indicated that there is a general lack of a totally acceptable model for compaction of very fine-grained clastic sediments. There are several apparently conflicting theories in the technical literature as to the genesis of shales, manner in which these rocks are compacted, and the mechanism by which the pore fluid is released during burial. Skempton, for example, believes that overburden load alone is not an effective agent in dewatering deeply buried shales. New concepts have been slow in coming forth following the early work of Athy and Hedberg. Several of the new concepts and compaction models are described in this chapter.

ROSE, V. C., and RONSY, J. R. 1971. "A Nuclear Gage for In-Place Measurement of Sediment Density," Offshore Technology Conference Preprints, Vol 1, Paper No. OTC1329, pp 43-52.

A nuclear gage for measuring sediment density in place is being developed under an Atomic Energy Commission contract. This gage will be added to the Deep Ocean Sediment Probe (DOSP), a multi-sensor system. The gage uses a gamma radiation isotope source in a concurrent transmission and backscatter arrangement. Direct correlation with undisturbed cores and acoustic data from the DOSP is possible. An electrical resistivity sensor is being added and will provide additional in-place data for correlation. Results of testing both laboratory and prototype design configuration are presented.

Transmission gages are usually superior to backscatter gages but require a two-probe fork arrangement which is more difficult to force into sediments than a single-probe backscatter-type arrangement. In the design presented, the backscatter gage arrangement has been optimized to approach transmission results by special design of radiation shields around the isotope source and radiation detector and by the design of energy level discriminating circuits in the instrumentation. This design limits the zone of material sensed to a well defined volume and avoids variations in readings resulting from changes in chemical composition of the sediment.

RUBEY, W. W. 1933. "Settling Velocities of Gravel, Sand, and Silt Particles," American Journal of Science, Vol 225, No. 145, pp 325-338.

The uniform settling velocity attained sooner or later by a falling particle depends upon the resistance offered by the settling medium. For small particles this resistance in turn depends chiefly upon the viscosity of the fluid, but for large particles it appears to be controlled almost entirely by impact. Small rounded quartz grains (very fine sand and silt) fall through water with the velocities given by Stokes' law of viscous resistance but coarse sand, pebbles, and boulders follow a totally different law.

Granting certain assumptions about the deflection of water, the impact of a rising current required to support a pebble can be deduced theoretically. Published data on settling velocities seem to confirm this deduction and they also suggest the approximate equivalence of these settling velocities to the velocities required to transport pebbles along the bed of a stream (of either water or air).

Stokes' law and the impact formula may be combined very simply into a general equation for the settling velocities of large and small grains. This general equation, which contains no empirical constants, accords very closely with published data on quartz grains but not so closely with data on fragments of galena.

RUMBOLTZ, M., ARTHUR, J. F., and BALL, M. D. 1976 (Mar). "Sediment Transport Characteristics of the Upper San Francisco Bay-Delta Estuary," Proceedings of the Third Federal Interagency Sedimentation Conference, pp 4-12 - 4-25, Sedimentation Committee, Water Resources Council, Washington, DC.

Sediment transport in the San Francisco Bay-Delta estuary of California is being investigated by an interagency, Federal, and state study group as part of an overall investigation to assess the impact of water resources development on the ecology of the estuary.

Analysis of the river discharge and suspended solids data (1960-1969) indicates that over 88 percent of the sediment discharge by the rivers to the delta originates in the Sacramento River basin. The analysis also indicates that during the November-through-April period, 80 percent of the annual sediment discharge from the rivers enters the delta. Suspended solids transport through the estuary is primarily controlled by river inflow, export pumping, tidal exchange, two-layered flow estuarine circulation, and surface wave action.

This paper presents a brief summary or sediment discharge to the bay-delta estuary and a general description of the factors influencing transport of sediments through the estuary.

RUTGERS, I. R. 1962a. "Relative Viscosity and Concentration," Rheologica Acta, pp 305-348, Dr. Dietrich Steinkopff-Verlag, Darmstadt, The Netherlands.

A survey is given of the many equations which have been proposed for describing the relation between relative viscosity and concentration of various disperse systems. The functions have been grouped in a formal array, which makes the connections clearer. It becomes evident then where further possibilities exist, where further elaboration has no use, and in which section experimental checking is needed or might be useful. The formulas have all been examined on their validity for suspensions of spheres. The very large number of equations proposed could be reduced to only five or even two or three really valuable functions. It is indicated that the same reduction should be sought for other types of disperse systems.

RUTGERS, I. R. 1962b. "Relative Viscosity of Suspensions of Rigid Spheres in Newtonian Liquids," Rheologica Acta, Vol 2, pp 202-210, Dr. Dietrich Steinkopff-Verlag, Darmstadt, The Netherlands.

Several investigations about the dependence of the relative viscosity on concentration have been described in the literature for rigid spheres of more or less monodispersoid character. A number of these results have been collected, choosing them for precision, great range of diameter, concentration or rate of shear, extreme fine particles size, or because they have been much cited in the literature or are otherwise illustrative.

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SAKAMOTO, W. 1972. "Study on the Process of River Suspension From Flocculation to Accumulation in Estuary," Bulletin of Ocean Research Institute, No. 5, pp 3-46.

The interactions between suspended matter carried by the river and sea water at the estuary are very interesting and important problems. Three things may happen to these particles when they mix with salt water and settle on the bottom: flocculation of colloidal particles, acceleration of settling velocity of solid or flocculated particles, and action of turbulent flow of the bottom water to stir up sediment from the sea floor. The flocculation phenomenon and settling velocity of colloidal clay particles were observed at an artificial interface of fresh and salt water by means of an optical microscope. Five kinds of clay and clay minerals were used: fine grain of quartz, talcum powder, illite, kaolinite, and montmorillonite. The composition of surface suspensions around the river mouth is compared with experimental results, and physical differences between them such as settling velocity and porosity of particles, density, and turbulence of water are discussed. When particles in suspension from the river come in contact with sea water, they develop quite a different shape called a "floc," which is very unstable and porous. The size of a floc sinking through salt water depends on both the concentrations of sea water and the suspensions themselves.

They stopped settling for several minutes at the boundary between two layers of different salinity. The time they remained at the boundary seemed to be proportional to the density of the saline water in the lower layer. This may be due to the density difference between the salt water and particles. The particles contain much fresh water in their pores which prevented them from settling until the fresh water became saline by the effect of salt diffusion from the lower water layer. The density of a floc which contains fresh water is defined as "virtual density." The settling times are compared with the theoretical values.

SANTSCHI, P. H., NIXON, S., PILSON, M., and HUNT, C. 1984. "Accumulation of Sediments, Trace Metals (Pb, Cu) and Total Hydrocarbons in Narragansett Bay, Rhode Island," Estuarine, Coastal and Shelf Science, Vol 19, pp 427-449.

The accumulation of sediments, trace metals, and hydrocarbons has been estimated from the analysis of the sediment from six coring sites in Narragansett Bay. Radionuclides ($^{234}Th_{xs}$, $^{210}Pb_{xs}$, $^{239,240}Pu$) with known input functions and trace metals (Cu, Pb) were used. The authors estimate that 6.9×10^4 tons of sediments, 51 to 90 tons of Pb, 72 to 100 tons on Cu, and 400 to 1000 tons of total hydrocarbons accumulate annually under present conditions in the bay. This represents 64 to 117 percent (Pb), 89 to 123 percent (Cu), and 23 to 58 percent (hydrocarbons), respectively, of present day inputs to the bay. Furthermore, close to 100 percent of the particle-reactive radionuclides ^{210}Pb and $^{239,240}Pu$ accumulate in the bay. Present day inputs to the bay were calculated independently as 77 to 80 tons Pb and 81 tons of Cu. Sewage effluents were the dominant source of Cu, whereas atmospheric deposition and urban runoff were most important for Pb. Dredging activities by the US Army Corps of Engineers between 1946 and 1971 removed more sediments from the bay than would have accumulated during the same time in the undredged areas of the bay. Copper smelting and coal mining on the shores of the upper bay during 1866-1880 left an imprint in the sediments which is still evident. Model-derived accumulation rates of Pb, Cu, and coal during that time were 3 to 4 times present-day inputs.

SARGUNAM, A., RILEY, P., ARULANANDAN, K., and KRONE, R. B. 1973 (Mar). "Physico-Chemical Factors in Erosion of Cohesive Soils," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 99, No. HY3, pp 555-558.

Hydraulic research has endeavored to relate a critical hydraulic shear stress, defined as that stress which must be exceeded to cause erosion of a soil, and mechanical properties of the soil such as bulk shear strength and Atterberg limits. Recent field investigations have shown that susceptibility of a cohesive soil to erosion depends on the pore fluid composition, as characterized by the total concentration of ions and the relative abundances of mono- and divalent ions. This paper presents additional information on the effects of pore-water composition on the resistance of a consolidated natural soil to surface erosion.

SARIKAYA, H. Z. 1977 (Aug). "Numerical Model for Discrete Settling," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 103, No. HY8, pp 865-876.

Sedimentation is an extensively applied treatment process for the removal of suspended solids from water and wastewater. The type of flow is generally turbulent in the settling tanks if tube settlers and shallow depth settling units are excluded. Therefore, settling of discrete particles can be investigated as the dispersion of settleable solids in the turbulent flow field under suitable boundary conditions that simulate the settling basins. In fact, dispersion models were applied to settling tanks as early as 1946 by Camp. In order to obtain an analytical solution, he assumed that velocity distribution is uniform in the vertical direction and that the turbulent diffusion coefficient is constant. However, it is known that velocity distribution is logarithmic and that distribution of the turbulent diffusion coefficient is parabolic along the vertical axis in a two-dimensional uniform open channel flow. Therefore, this study investigates the phenomenon of discrete settling by employing experimentally verified velocity and turbulent diffusion coefficient functions and a numerical method of analysis, in order to get results analogous to those given earlier for a simplified case.

The dispersion equation written for discrete settleable particles is solved by the finite-difference technique for three different velocity distribution functions in the vertical direction: uniform, parabolic, and logarithmic. Thus, the effect of velocity distribution on sedimentation efficiency is also determined. For simplicity, it is assumed that the turbulence is isotropic and that the settling velocity of a particle in the turbulent flow is equal to the quiescent settling velocity of the same particle.

The differential equation describing the dispersion of settleable discrete particles in two-dimensional uniform open channel flow has been solved by a finite difference method. Settling efficiency has generally been expressed in terms of two independent variables when longitudinal turbulent diffusion is ignored. Several solutions have been obtained by assuming different velocity distributions in the vertical direction and for various parameters so as to cover their range in practice. The effect of turbulence and velocity distribution is graphically presented. Solutions given for experimentally verified logarithmic velocity distribution are suggested for practical application. In the case of uniform velocity distribution, results of the numerical solution have been compared with results of the analytical solution, and excellent accuracy was obtained.

SAYRE, W. W. 1969 (May). "Dispersion of Silt Particles in Open Channel Flow," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 95, No. HY3, pp 1009-1038.

Some aspects of dispersion processes in streams have been investigated rather intensively in recent years. Much progress has been achieved in developing criteria for predicting the longitudinal dispersion of substances, such as dissolved or suspended colloidal dispersants, which behave like the ambient fluid. The term "dispersant," as used in this paper, means the substance which is being dispersed. Once initial mixing throughout the stream cross section has occurred, this class of dispersants is transported at the mean stream velocity, and dispersed longitudinally by the combined action of turbulent diffusion and differential convection due to the variation of velocity with respect to position in the cross section. Research on the transport and longitudinal dispersion of dispersants which behave like bed-material sediment particles has also yielded results. Bed-material particles tend to move in a sequence of discrete steps of random length that are separated in time by rest periods of random duration. Hence, they are transported at rates which are much less, frequently by several orders of magnitude, than the rates for dissolved or continuously suspended materials.

Between these extremes is the class of dispersants typified by silt and fine sand which are transported mainly in suspension. While suspended they behave much like fluid or colloidal particles except that they tend to settle and are eventually deposited on the bed. There they behave like bed-material particles until they are re-entrained in the flow.

This paper is concerned mainly with the dispersion process for the intermediate class of dispersants. However, the neutrally-buoyant dissolved dispersant is included as a limiting case of the more general problem of denser particulate dispersants. The investigation reported herein is restricted to dispersion in a uniform, two-dimensional, turbulent shear flow in an open channel. The only initial condition considered is an instantaneous plane source that is uniformly distributed over the flow cross section. It is assumed that local values of the vertical turbulent transfer coefficients for mass and momentum are equal, and that the mean fall velocity of particles is not affected by turbulence.

SCHNEIDER, J. F. 1975. "Recent Tidal Deposits, Abu Dhabi, UAE, Arabian Gulf," Tidal Deposits, R. N. Ginsburg, ed., Section III, Chapter 24, pp 209-214, Springer-Verlag, New York.

This chapter describes the recent tidal deposits of Abu Dhabi, Arabian Gulf. The author explains the hydrography, climate, and physiographic-hydrographic subdivisions and distinguishes the stratigraphic sequence of the Sabkha, Southwest Abu Dhabi.

SCHUBEL, J. R. 1972. "Distribution and Transportation of Suspended Sediment in Upper Chesapeake Bay," <u>The Geological Society of America, Inc., Memoir</u>, Vol 133, pp 151-167.

In the upper reaches of the Chesapeake Bay there occur two distinctive distributions of suspended sediment and associated patterns of sediment transport. During the spring freshet, the Susquehanna River overpowers the characteristic net nontidal estuarine circulation in the upper 20 to 30 kilometres of the estuary, and the net flow and sediment transport are seaward at all depths. The marked decrease seaward of the concentration of suspended sediment in the upper bay reveals the close link, during the freshet, between the suspended sediment population and the principal ultimate source of sediment--the Susquehanna River.

With subsiding river flow the net nontidal estuarine circulation is reestablished in the upper bay, and a turbidity maximum is formed. The high concentrations of suspended sediment, greater than those either farther upstream in the source river or farther seaward in the estuary, are produced and maintained primarily by the periodic resuspension of bottom sediment by tidal scour and by the sediment trap created in the upper reaches of the estuarine circulation regime.

SCHUBEL, J. R. 1971a. "Sedimentation in the Upper Reaches of the Chesapeake Bay Estuary," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 4, pp 235-244.

In the upper Chesapeake Bay there are two distinctive patterns of the distribution of suspended sediment and associated patterns of sediment transport. During periods of very high river flow the Susquehanna River dominates the circulation in the upper 20 to 30 km of the bay, and the net flow and sediment transport are seaward at all depths. There is a marked decrease of the concentration of suspended sediment downstream from the river's mouth. During the spring freshet the bulk of each year's supply of fluvial sediment is introduced, and more than 70 percent of it is deposited in the upper 30 km of the Bay.

With subsiding river flow the net nontidal estuarine circulation is reestablished in the upper reaches of the bay, and the concentrations of suspended sediment are greater within the upper bay than either farther upstream in the source river or farther seaward in the estuary. These anomalously high concentrations are produced and maintained by a combination of physical processes--by the periodic resuspension of bottom sediments, by tidal scour, and by the sediment trap created in the upper reaches of the estuarine circulation regime by the net nontidal circulation.

SCHUBEL, J. R. 1969. "Size Distributions of the Suspended Particles of the Chesapeake Bay Turbidity Maximum," Netherlands Journal of Sea Research, Vol 4, No. 3, pp 283-309.

It has been suggested by Postma that the suspended particles in a turbidity maximum produced by the net nontidal estuarine circulation should have a narrow size distribution. Particles larger than a certain size would presumably be deposited while smaller particles would be carried out of the area by the net seaward flow of the upper layer. There have been very few pertinent data to support or deny this suggestion.

An intensive investigation of the Chesapeake Bay's turbidity maximum has shown that its suspended particle population is determined by the physical processes, local resuspension, and the net nontidal estuarine circulation, which combine to produce the turbid zone, and that the suspended particles have a narrow size distribution both in terms of equivalent projected diameters and Stokes' diameters or settling velocities. Determinations were made both of the number-size distribution by a photomicrographic technique and of the volume-settling velocity ("size") distributions by a sedimentation technique.

The suspended particle population of the Chesapeake Bay's turbid zone is composed of two subpopulations. One subpopulation is comprised of particles with settling velocities of the same order as the vertical mixing velocities. These particles form a "natural background" of suspended sediment found throughout the water column and whose concentration and particle size distribution are very uniform over periods of weeks or months. The second subpopulation consists of particles which are alternately suspended and deposited. The presence of this subpopulation is made manifest by semitidal fluctuations of the concentration of suspended sediment in the lower layer at stations deeper than about 4 m and throughout the water column at shallower stations. The fluctuations produced by tidal "scour and fill" are accompanied by marked changes in the volume-size distribution and increase in magnitude near the bottom--the sediment source.

SCHUBEL, J. R. 1968a (Mar). "Suspended Sediment of the Northern Chesapeake Bay," Technical Report No. 35, pp 89-128, Chesapeake Bay Institute, The Johns Hopkins University, Baltimore, Md.

An intensive study was made of the suspended sediment of the northern Chesapeake Bay from 21 March 1966 through 31 March 1967. Samples were collected routinely at 16 stations for determinations of both the concentrations of total suspended solids and the concentrations of combustible organic matter. At selected stations samples were collected for mineral identification by X-ray diffraction and for size analysis both by a photomicrographic technique and by sedimentation.

During the period of peak runoff the upper bay's suspended sediment population was closely linked to its major source of new sediment--the Susquehanna River. At all other times of the year however, the concentrations of suspended sediment were higher within the bay than in the mouth of the Susquehanna River despite the dilution of the Susquehanna discharge and the settling out which occur within the bay. Excluding the period of maximum runoff, the concentrations of suspended sediment in the bay were determined largely be local resuspension and by the upstream transport of sediment in the lower layer. It is not possible to assess the relative contributions by these two mechanisms with the data we now have. It was possible however to calculate the net flux density of sediment through the surface separating the upper and lower layers.

SCHUBEL, J. R. 1971b. "Tidal Variation of the Size Distribution of Suspended Sediment at a Station in the Chesapeake Bay Turbidity Maximum," Netherlands Journal of Sea Research, Vol 5, No. 2, pp 252-266.

In an earlier paper in this journal, Schubel reported the results of photomicrographic and sedimentation size analyses of the suspended particles of the turbidity maximum at the head of Chesapeake Bay. The samples, collected from the surface, middepth, and one meter off the bottom at a number of stations during different seasons, demonstrated that the suspended particles have a narrow size distribution which is relatively uniform both temporally and spatially. The general tendency for the size distributions, both number and volume, to be shifted toward larger sizes near the bottom was attributed to the resuspension of slightly coarser and pelleted bottom sediment by tidal scour. Although the importance of tidal currents in resuspension had been established, none of the samples whose analyses were reported was collected at known phases of the tide or at measured current velocities.

The effectiveness of tidal currents as an agent of resuspension is clearly demonstrated and shows that there is a "natural background" of suspended particles which increases with depth and whose intensity at any depth is relatively constant over time scales of two tidal cycles. Other observations indicate that it is uniform over weeks or months. In the lower layer superimposed upon this "natural background" are semitidal fluctuations of the concentration of suspended solids which increase in magnitude near the bottom--the sediment source. The suspended particle population is thus comprised of two subpopulations: those particles with settling times long compared to the semitidal period which are in more or less continual suspension (the background subpopulation) and those particles which are alternately suspended and deposited by the waxing and waning of the tidal currents. The size distributions of the background subpopulations at the surface and at middepth have been described in detail, but at that time, no time series analyses were available to establish the tidal variations of the size distribution of the transient subpopulation of particles in the lower layer.

This paper presents the results of sedimentation size analyses of samples collected over a tidal cycle at a station within the turbidity maximum of the Chesapeake Bay. Samples of suspended sediment were sized at hourly intervals from 0.5 and 1.5 m above the bottom. Surface samples were sized for alternate hours to establish the stability of the size distribution of the sub-population of "background" particles.

SCHUBEL, J. R. 1968b (Sep). "Turbidity Maximum of the Northern Chesapeake Bay," Science, Vol 161, pp 1013-1015.

The turbidity maximum near the head of the Chesapeake Bay is produced primarily by the local resuspension of bottom sediments, and by the estuarine "sediment trap" which is formed in the upper reaches of the estuarine circulation regime by the net nontidal circulation.

SCHUBEL, J. R., and WILLIAMS, A. D. 1976 (Nov). "Dredging and Its Impacts on Upper Chesapeake Bay: Some Observations," Proceedings, Second Annual Conference, The Coastal Society, pp 70-115.

Baltimore Harbor is located at the head of the Patapsco estuary, a small tributary arm of the upper Chesapeake Bay. The upper Chesapeake Bay is a region of naturally high sedimentation rates, and shipping channels must be maintained by relatively frequent dredging. Historically, the bulk of the material dredged from Baltimore Harbor has been disposed of on wetlands or fastlands adjacent to the harbor, or overboard within the harbor. The bulk of the material dredged form the connecting channels and from the approach channel to the Chesapeake and Delaware Canal has been disposed of overboard within the upper bay, and the bulk of the material dredged from the canal itself has been deposited on lands bordering the canal.

The Port of Baltimore is Maryland's most important economic component, but the upper Chesapeake Bay and the Chesapeake and Delaware Canal are not only major shipping avenues, they are also important spawning and nursery areas for a variety of commercially and recreationally important finfish. And, the main body of the bay adjacent to Baltimore Harbor has important shellfish beds. The perceived conflict between fisheries and dredging and disposal, coupled with more stringent criteria that have been promulgated in recent years for disposal of dredged materials in open waters, has resulted in prolonged delays in carrying out dredging projects, sometimes with significant economic perturbations.

SCHUBEL, J. R., WILSON, R. E., OKUBO, A. 1978. "Vertical Transport of Suspended Sediment in Upper Chesapeake Bay," Estuarine Transport Processes, B. Kjerfve, ed., pp 161-177, University of South Carolina Press, Columbia, SC.

Determinations of the vertical flux densities of total suspended sediment through a series of imaginary planes at fixed levels above the bottom at a station in upper Chesapeake Bay showed that the flux densities vary markedly in magnitude and direction over a tidal cycle, and that the magnitude of these fluctuations increases near the bottom. The total flux density is relatively uniformly apportioned among particles with Stokes' diameters ranging from about 2 μm to 64 μm. Smaller and larger particles contribute relatively little to the total flux density. The flux density attributable directly to particle-by-particle settling according to Stokes' law is sufficiently large to account for the marked decreases in the mass of suspended sediment following peak concentrations of suspended sediment and peak current velocities on both flood and ebb. The mechanism of flocculation is therefore not required to explain the large semitidal variations of the concentration of suspended sediment in the lower part of the water column.

SCHULTHEISS, P. J. 1982. "Geotechnical Properties of Deep Sea Sediments: A Critical Review of Measurement Techniques," Report No. 134, Institute of Oceanographic Sciences.

This report presents a critical examination of the techniques employed for assessing the geotechnical properties of deep sea sediments. The review includes an introduction into some of the basic soil mechanics principles as well as highlighting the very important differences between terrestrial soils and ocean sediments. Central to the theme of this review is an analysis of the type of sample that is necessary for specific geotechnical tests or whether in-situ tests need to be performed. Emphasis is placed on the problems of obtaining relatively undisturbed samples from the sea bed together with a discussion of the various parameters which cause disturbance, including the problems of large reductions in hydrostatic pressures. Apart from destructive mechanical tests, the use of nondestructive testing, especially acoustic, on both samples and in situ have been examined.

It is concluded that, because all samples have suffered a significant amount of disturbance, very few laboratory tests can have high levels of confidence. Further studies are required to examine the effects of disturbance in a controlled manner before it is possible to evaluate the reliability of most laboratory tests. In-situ testing, while inherently expensive, can provide rapid and reliable answers providing that the tests are designed for specific purposes rather than attempting to use universal testing procedures.

SHELDON, R. W. 1968 (Jan). "Sedimentation in the Estuary of the River Crouch, Essex, England," Limnology and Oceanography, Vol 13, No. 1, pp 72-83.

The coast of Essex is bordered by marshland and is subsiding. Under natural conditions sedimentation on the marshes keeps pace with subsidence, but where the land has been reclaimed and embanked, subsidence has continued with no compensating sedimentation.

Material in suspension is flocculated and is mainly inorganic but may contain up to 25 percent organic material. Particle diameters of the flocculi range from less than 1 μ to about 80 μ with a mean at about 10 to 15 μ. The concentration varies with state of tide, depth, and location. There is more material near the bottom than at the surface, and greater concentrations occur near the mouth than near the head of the estuary.

Bottom deposits are made up of two distinct particle populations. There is a fine sand fraction which is believed to be transported near the bottom, and a silt fraction derived from suspension. Offshore, in areas exposed to wave action, there are fine sands with very little silt. The proportion of silt increases and the modal diameter of the fine sand fraction decreases towards the head of the estuary.

The sediments may be derived from offshore deposits of boulder clay, and evidence was found to suggest that these deposits are being eroded by tidal currents. Material eroded from an unsorted boulder clay could produce the distribution of sedimentary properties found in the Essex estuaries.

SHENG, Y. P., and LICK, W. 1979 (Apr). "The Transport and Resuspension of Sediments in a Shallow Lake," Journal of Geophysical Research, Vol 84, No. C4, pp 1809-1826.

The time-dependent flow and dispersion of suspended sediments in the western basin of Lake Erie are being studied by means of numerical models utilizing data from remote-sensing studies and flume experiments. Mechanisms of sediment dispersion included in the models are convection and turbulent diffusion, river loading, gravitational settling, and physical resuspension and deposition at the sediment-water interface. The time-dependent currents are computed by means of a free surface hydrodynamic model. A wave-hindcasting model is used to compute the wave parameters needed for estimation of shear stress generated at the sediment-water interface under given wind conditions. The rate of sediment resuspension as a function of bottom shear stress and sediment properties is based on data from flume experiments using lake sediments. A series of numerical calculations with the models was performed on a two-dimensional lake with a variable bottom representing a transverse cross section of Lake Erie. It was found that wind direction and fetch length can significantly affect the sediment dispersion patterns. The two-dimensional and the three-dimensional models were both used to simulate realistic short-term events in Lake Erie, and the model outputs compare favorably with the synoptic surface sediment dispersion patterns deduced from the multispectral scanner data.

SHIDELER, G. L. 1975 (Sep). "Physical Parameter Distribution Patterns in Bottom Sediments of the Lower Chesapeake Bay Estuary, Virginia," Journal of Sedimentary Petrology, Vol 45, No. 3, pp 728-737.

Bottom sediments within the lower Chesapeake Bay between the Potomac River and the Atlantic Ocean were analyzed for mud content, sand texture, organic content, and color. Parametric distribution patterns indicate a complex dispersal model, in which sediments are derived from multiple sources. The bay region between the Potomac and York Rivers appears to be an effective mud trap, with the central basin constituting a uniformly colored mud depocenter, while the marginal zones are composed of multicolored residual sand deposits. The baymouth sector south of the York River is a multicolored sand province that constitutes an effective mud-bypass area. A regional belt of highly organic sediments occurs throughout the lower bay which reflects a zone of high benthonic shell concentrations. Sand textures suggest a composite fabric of modern equilibrium sediments, and palimpsest sediments that reflect an earlier hydraulic regime. The palimpsest sediments may represent Pleistocene fluvial deposits of the ancestral Susquehanna drainage system, and early Holocene paralic deposits generated during the bay's inundation.

SIEGENTHALER, C., HSU, K. J., and KLEBOTH, P. 1984 (Apr). "Longitudinal Transport of Turbidity Currents--A Model Study of Horgen Events," Sedimentology, Vol 31, No. 2, pp 187-193.

Experiments were carried out in a 10- by 6-m basin to simulate turbidity currents generated by the Horgen Slumping Events of 1875. The conditions for kinematic similarity were satisfied and the experiments gave further insight into the mechanics of transport triggered by the Horgen slumps. The experimental turbidity currents laid down thick deposits on a subaqueous fan, and thin sheets of turbidite on the floor of the elongate basin through longitudinal transport, comparable with the simulated deposits in Lake Zurich. It is concluded that longitudinal transport is a general phenomenon of turbidity currents.

SIMMONS, H. B. 1965. "Channel Depth as a Factor in Estuarine Sedimentation," Technical Bulletin No. 8, pp 11-15, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

In most of the estuaries in the United States which have been improved for navigation by large oceangoing vessels, drastic changes have taken place in both annual shoaling rates and in the locations of major shoal areas as the channels were progressively deepened. Numerous problems which affect channel maintenance have arisen because of these changes, and some of these problems have now reached a critical state.

This paper presents a case history of Savannah Harbor to illustrate how shoaling rates and patterns have been changed by progressive changes in channel depth. The paper also discusses the more important reasons for such changes and suggests remedial measures which appear to offer both technical and economic solutions to certain of the problems thus created.

SIMMONS, H. B. 1966. "Field Experience in Estuaries," Estuary and Coastline Hydrodynamics, A. T. Ippen, ed., Chapter 16, pp 673-689, McGraw-Hill, New York.

This chapter contains information pertaining to field experience in estuaries. The field experience includes tidal currents, salinity-generated currents, types of estuary mixing, dredging and spoiling practices, and sedimentation.

SIMMONS, H. B., and BOBB, W. H. 1965 (Sep). "Hudson River Channel, New York and New Jersey, Plans to Reduce Shoaling in Hudson River Channels and Adjacent Pier Slips; Hydraulic Model Investigation," Technical Report No. 2-694, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A comprehensive model which correctly reproduced tides, tidal currents, density currents, and shoaling in the entire New York Harbor complex was used to study plans for reducing maintenance dredging. Bottom currents in the problem reach, between the Battery and the George Washington Bridge, are predominantly in an upstream direction. This is probably the most important single factor affecting shoaling of this reach. The presence of a reduced cross-sectional area of the Hudson at the George Washington Bridge, supplemented by the effects of an influx of highly saline waters entering the Hudson River form the Harlem River, interrupts the upstream predominance of bottom flow, and sediments, being carried out of the critical harbor area, are resuspended and returned downstream. The process is repeated until the sediments are deposited in areas of relatively low current velocity, notably the pier slips and/or shoal areas in the navigation channels. The elimination of either or both of these interruptive features would materially reduce shoaling in the harbor for all upland flow conditions tested.

Sediment basins located in two general areas were tested. The sediment basins would generally reduce shoaling in existing shoal areas; however, total dredging would not be reduced, since the shoaling rate in the basin would generally be increased considerably, and since the basin would have to be dredged periodically to maintain its effectiveness. Basins could effect economies by providing additional use time for channel and slip areas, by concentrating sediment adjacent to convenient disposal areas, and by lowering the unit dredging cost as a result of material location (slip dredging cost is twice as much per cubic yard as channel dredging) and as a result of concentrating a larger volume in one location.

The benefits of the recommended improvement plan, which includes enlargement of the Hudson River cross section at the George Washington Bridge, would be significantly increased by prohibiting the Harlem River from flowing into the Hudson. Closure of the Harlem during the normal period of westerly flow therein would also significantly reduce the redeposition of material in the proposed enlarged section at the George Washington Bridge.

SIMMONS, H. B., and HERRMANN, F. A., JR. 1972. "Effects of Man-Made Works on the Hydraulic, Salinity, and Shoaling Regimens of Estuaries," The Geological Society of America, Inc., Memoir, Vol 133, pp 555-570.

Within the relatively recent past, many works of man have been constructed in estuaries and in their freshwater tributaries in the interest of improving navigating conditions, or regulating the river flow for hydroelectric power generation and (or) flood control. In some cases such works have produced major and sometimes undesirable changes in the hydraulic, salinity, and shoaling characteristics of the estuaries involved. The undesirable effects have in some cases been so drastic that the overall effects may have been detrimental rather than beneficial.

The works of man have influenced the hydraulic, salinity, and shoaling regimens in the passes of the Mississippi River, the lower Savannah River, and Charleston Harbor. The histories of these changes strongly recommend that any proposed changes should be thoroughly evaluated by all practicable means before their implementation to insure that the proposal will be beneficial to the system as a whole.

SIMMONS, H. B., and RHODES, H. J., JR. 1965 (Aug). "Plans for Reducing Shoaling, Southwest Pass, Mississippi River; Hydraulic Model Investigation," Technical Report No. 2-690, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

Southwest Pass, one of the three major outlets of the Mississippi River, is the principal navigation channel between the Gulf of Mexico and New Orleans, LA. At the time of the model study reported herein, it was being maintained to provide a navigation channel 35 ft deep by 800 ft wide from Head of Passes to the ends of the jetties (21.2 miles below Head of Passes) from whence a bar channel 35 ft deep by 600 ft wide extended into the gulf. Maintenance of the channels is a continuing and expensive problem due to extensive shoaling, primarily near the ends of the jetties and to some extent throughout the entire length of the Pass. Most of the shoaling in the jetty channel occurs during time of high freshwater discharge. The model study was conducted to determine the effectiveness of proposed plans (jetty extensions and channel realignments and contractions) for the elimination or reduction of maintenance dredging in the jetty and bar channels, and effects of deepening the channels to 40 ft.

The model, constructed to linear scale ratios of 1:500 horizontally and 1:100 vertically, reproduced the lower 12 miles of Southwest Pass and the gulf area adjacent to the pass. Provisions were made for reproducing prototype tides, tidal currents, littoral currents, and wave action in the gulf and saltwater and freshwater flows in the pass and bar channel. Shoaling studies involving various mixtures of granulated plastics simulating prototype shoaling materials revealed that the model satisfactorily reproduced the shoaling patterns and distribution that occur in the prototype. Tests of proposed plans for reducing shoaling indicated that plans involving a curved realignment for the jetty channel and plans involving relocating the bar channel upstream from the downstream ends of the jetties would greatly reduce shoaling for a 42-ft-deep channel (authorized project depth of 40 ft plus overdredging allowance of 2 ft) as compared with a 42-ft-deep channel on the alignment of the existing channel. Tests indicated that reducing the channel width throughout the pass from 800 to 600 ft would also be beneficial.

SIMPSON, H. J., OLSEN, C. R., TRIER, R. M., and WILLIAMS, S. C. 1976 (Oct). "Man-Made Radionuclides and Sedimentation in the Hudson River Estuary," Science, Vol 194, No. 4261, pp 179-183.

Recently deposited fine-grained sediments in the Hudson River estuary contain radionuclides from global fallout produced by atmospheric bomb tests as well as from low-level releases of a local nuclear reactor. Accumulation rates of these nuclides are dependent on rates of sediment deposition and vary with location in the estuary by more than two orders of magnitude. Within the Hudson estuary, New York Harbor is currently the zone of most rapid deposition of sediments containing radionuclides, some of which were released from a nuclear reactor about 60 kilometres upstream of the harbor.

SKEMPTON, A. W. 1970 (Apr). "The Consolidation of Clays by Gravitational Compaction," Quarterly Journal of the Geological Society of London, Vol 125, pp 374-407.

Sedimentation compression curves, relating void ratio to effective overburden pressure, are presented for a wide lithological range of argillaceous deposits. These curves show the progressive changes from recently deposited muds on the sea floor, to Quaternary clays at depths of several tens of metres, and finally to hard clays and mudstones of Pliocene age at depths extending to about 3,000 m. Twelve localities are examined in some detail and information is also given from another eight previously published sites. In all cases the data are derived from 'normally-consolidated' deposits, strata which have never been under greater pressures than those existing at the present time. This procedure eliminates the difficulties of estimating the effect of pressure reduction by erosion. Clays containing high proportions of carbonates and organic matter are not included in this study.

At any particular effective overburden pressure the water content of a normally consolidated clay is directly related to the amount of clay minerals present and to their colloidal activity. The combined influence of these two factors can be indicated quantitatively by the Atterberg limits; and at a given value of ρ the water content is found to be a function of the Atterberg (liquid and plastic) limits for all inorganic noncalcareous clays except those with an extremely unstable microstructure, such as the so-called 'quick clays' of Scandinavia. Moreover, the water contents of muds on the sea bed or in tidal flats can also be expressed approximately by single-value parameters in terms of these limits. Thus if the water content, effective overburden pressure, and Atterberg limits are known for an individual layer of normally consolidated clay, it is possible to reconstruct the entire sedimentation compression curve for that clay with a reasonable degree of certainty; and hence an estimate can be made of the compaction which has occurred in the clay under its own weight and under the load of any overlying strata.

At some of the sites, in addition to data relating to compaction, information is given on the increase in strength with depth and the rate of deposition as deduced from radiometric dating.

SLY, P. G., THOMAS, R. L., and PELLETIER, B. R. 1983. "Interpretation of Moment Measures Derived From Water-Lain Sediments," Sedimentology, Vol 30, pp 219-233.

Although mean size provides a useful value for characterizing sediments, it is an inadequate expression of the interaction between sediments and hydraulic regimes and many authors have explored the significance of other statistical moment measures in different parts of the particle size spectrum. Few publications, however, have described such relationships over a very wide range of particle sizes. Using a combined data base (of marine and lacustrine sediments) we have been able to demonstrate the following:

The distributions of standard deviation (and entropy) values are repeated in similar form on either side of the sand size class, describing mixtures between sands and gravel and sands and clay.

Skewness is modified by the hydraulic response of the sediment and a skewness divide is present at about 2.7 ϕ, where it coincides with the minimum shear velocity required to initiate particle motion. This divide may be used to distinguish between high- and low-energy regimes.

Kurtosis, like standard deviation, is a measure of the mixing of end member populations but it is more sensitive to changes in the tails of distribution curves. The maximum positive peak of kurtosis, at about 2.5 ϕ, lies close to the skewness divide (in the authors' data).

By using skewness/kurtosis plots it is possible to define separate field distribution for sediments which, to a greater or lesser degree, appear to conform to hydraulic equilibrium.

By using sediments which are close to equilibrium (and lie at or close to the authors' skewness/kurtosis boundary) curves, it should be possible to define hydraulic shear velocities, at the time of formation. Values may be established by empirical relationships or by defining the break-point (traction and intermittent suspension) between linear components of individual sample ϕ size/probability distribution plots. Such relationships should be enhanced by using hydraulic equivalent diameters instead of sieve diameters.

In fine sediments, the use of fractional (silt:clay) ratios offers sensitivity at a level comparable to that of skewness/kurtosis plots and may be more easily computed.

SMERDON, E. T., and BEASLEY, R. P. 1959 (Oct). "The Tractive Force Theory Applied to Stability of Open Channels in Cohesive Soils," Research Bulletin 715, Agricultural Experiment Station, University of Missouri, Columbia, Mo.

The tractive force theory presents a logical criterion by which the problem of the stability of open channels in cohesive soils can be investigated. The purpose of this study was to investigate a number of cohesive soils, both in a physics laboratory and in a hydraulic flume, to determine it the critical tractive force could be correlated to the physical properties of the soils.

The data from the hydraulic tests and physical tests on the soils were analyzed statistically to determine the significance of the apparent correlation between critical tractive force and pertinent soil properties. For the soils tests, the critical tractive force was found to be well correlated with each of the following soil properties: (a) the plasticity index, (b) the dispersion ration, (c) the mean particle size, and (d) the percent clay. A less significant correlation existed between critical tractive force and the phi-mean particle size.

The data indicated that the critical tractive force exhibited a logarithmic relationship to the soil properties selected for analysis. Therefore, in the statistical analysis, it was often more fruitful to use the common logarithms of the values instead of the values themselves. This procedure permitted straight-line regression equations to be fitted to the experimental data. To evaluate the scattered the experimental points about the regression line, the standard deviations from regression were determined for each set of data.

The results of the study indicate that the following conclusions can be drawn: (a) The problem of the stability of open channels in cohesive soils can be studied on the basis of the tractive force theory. (b) The critical tractive force in cohesive soils is related to certain physical properties of the soils. Therefore, the effect of soil cohesion on open channel stability can be determined by physical tests of the soils. And (c), for the soils tested, the critical tractive force best correlated to either the plasticity index or the dispersion ratio, although good correlation also exists between the critical tractive force and either mean particle size or the percent clay.

SMITH, D. D., and GRAHAM, K. F. 1976 (Nov). "Relative Significance of Contemporary Dredging Impacts in San Diego Bay, An Historically Stressed Environment," Proceedings, Second Annual Conference, The Coastal Society, pp, 3-30, New Orleans, La.

For nearly a century prior to 1963, San Diego Bay was heavily stressed by four types of man's activities: (a) diversion and damming of all principal tributary drainages, with virtual elimination of freshwater input to the bay; (b) dredging and filling so extensive that only 17 to 18 percent of the original bay floor remains undisturbed; (c) discharge of sewage and primary effluent, industrial wastes, and power plant cooling water to the bay; and (d) intensive urbanization of adjacent lands.

In light of this historic setting, the environmental impacts of contemporary dredging activities would appear to be of relatively minor significance. However, since the 1960's dredging projects have been rigorously regulated and widely opposed by environmental groups. Specifically, in recent years, institutional constraints brought to bear through Federal and state regulatory processes have become key determinants in the authorization of dredging projects in California. Dredging permit procedures require review by numerous Federal, state, county, and municipal agencies as well as citizen interest groups. Opposition to a project by an agency or group may result in costly delays, possible project modification, or even cancellation.

A current dredging project in San Diego Bay provides a "real world" case history illustrating how environmental considerations and associated institutional constraints can modify dredging practices, delay project schedules, and increase costs, even in a historically stressed environment.

SMITH, T. J., and TAKHAR, H. S. 1979. "The Effect of Stratification on the Turbulent Transport of Mass and Momentum," Proceedings, XVIII Congress of the International Association for Hydraulic Research, Vol 3, pp 79-86.

The quantification of the effect of density stratification on the turbulent exchange coefficients and their associated mixing lengths was considered. The results were compared with available experimental data and are shown to accurately reproduce observed conditions. Two fundamental physical parameters were identified: the critical flux Richardson number and the turbulent Schmidt number under conditions of neutral stability, $S_c(R_f = 0)$. The theoretical results were shown to be sensitive to the value of the critical flux Richardson number, the magnitude of which was found to depend on flow geometry.

It was concluded that the proposed relationships were applicable to a wide range of environmental and laboratory flows.

SOLLITT, C. K., and CRANE, S. D. 1975. "Physical Changes in Estuarine Sediments Accompanying Channel Dredging," Proceedings, Fourteenth Coastal Engineering Conference, Vol II, pp 1289-1303.

The physical characteristics of estuarine sediments provide useful information about sediment sources, the nature of bottom surface stresses, and sediment transport mechanisms. Changes in sediment composition and state are also useful indicators for estimating the effects of unnatural stresses on dependent chemical and biological activities. In this study, the changes in several sediment properties have been monitored for an isolated estuarine dredging project.

The effect of estuarine hopper dredge activities has been evaluated for an Army Corps of Engineers project at Coos Bay, Oregon. The project included suction head dredging at a shoal area within the navigation channel and in bay spoiling at a deep section of channel one mile downstream from the dredge site. Core samples were taken five days before dredging and two, thirteen, and seventy days after dredging at the dredge and spoil sites. Subsequent laboratory analysis of the core samples revealed that dredging-induced redistribution of bottom sediments produced significant changes in several physical characteristics of the dredged material. Repeated resuspension of bottom sediments during the dredging and spoiling operations caused a net loss of fine-grained sediments and light organic constituents. Several symptomatic changes were observed which validate this finding, including: an increase in median grain size and decrease in uniformity of dredge spoils due to loss of fine fractions; a decrease in volatile solids in the dredge spoils due to a net loss of organics; a decrease in porosity at the spoils site due to the ability of the coarse grain sediments to resist resuspension; and a decrease in hydroscopic moisture content due to loss of porous organics and silt-clay material from the spoils.

Conditions following dredging were observed for a period of seventy days. Partial recovery of the sediment system was observed after two weeks with no further recovery in two months. The initial recovery came about due to the availability of local sources of resuspended sediment adjacent to the dredge site. This occurred under low-flow conditions in early fall. Complete recovery of the system was not observed and probably requires the relatively large sources of sediment which accompany heavy winter and spring runoff. Thus, the immediate effects of dredging may persist until the annual cycle of sediment erosion and deposition have occurred.

SPRING, V. F. 1938 (May). "Shoaling in Wilmington Harbor Since Construction of South Jetty," Memorandum for District Engineer, US Army Engineer District, Philadelphia, Philadelphia, Penn.

Wilmington Harbor, or the reach of Christiana River channel now known as Wilmington Harbor, has shoaled rapidly throughout project history. Experience has shown that the various increases in channel dimensions have always resulted in increased shoaling rates.

The study included consideration of the possibility that upland sources of shoaling material contributed heavily to Wilmington Harbor deposits. It was definitely concluded that not more than 12,000 cubic yards of material are brought down by Christiana and Brandywine Rivers during an average year. This is about 1 percent of the annual deposits found in Wilmington Harbor.

The study showed conclusively that the flood current velocity in the harbor is so low that deposition of practically the whole silt burden occurs in Wilmington Harbor. It also showed that the ebb current does not even approach scouring velocity.

Consideration of feasible means for correcting this situation led to the conclusion that a condition of self maintenance cannot be approached until current velocities through the harbor and in portions of the upper river are increased to beyond critical.

The mean maximum ebb current velocities cannot be increased to beyond critical by constriction of the cross-section through the harbor reach unless the project be modified so as to provide for a narrower channel. Constrictive works which do no encroach upon the existing channel are therefore not the solution to the difficulty.

It is concluded that provision of about 1,800 acres of additional tidal area and the construction of a wall 100 ft north of the north edge of the channel from the end of the jetties to opposite Lobdell Canal would increase the harbor current velocities by constriction, and the enlargement of the tidal basin would increase the velocity by increasing the volume of the tidal prism. It is probable that the maximum ebb velocity in the new regimen which would result from these extensive works would be about 2 feet per second, which would be sufficient to cause scour.

STORM, D. R. 1975. "A Predictive Method for Assessing the Impact of Maintenance Dredging in an Estuary," Proceedings, International Oceanic Development Conference, Vol 5, pp 169-186.

The physical, chemical, and biological processes which are altered during a typical maintenance dredging operation are analyzed. A conceptual model is used to relate the various processes and to serve as a guide in preparing dynamic models for quantification of key parameters such as suspended sediment transport and deposition. Actions and processes during the dredging and post-dredging period are discretely separated into dredging, spoiling, and equilibration categories. Equilibration in the estuary is manifested in (a) adjustments in the system hydraulics to satisfy the basic laws of conservation of mass and energy and (b) recruitment, colonization, and reestablishment of benthic communities for the new set of environmental conditions.

A prototype estuarial system, Bolinas Boat Channel, Bolinas, California, is selected to demonstrate the predictive possibilities of the impact analysis methodology. The methodology is tested on a proposed project to dredge shoal materials from the mouth of the Bolinas Boat Channel. A hydrodynamic, numerical model is modified to accommodate a velocity-suspended sediment function for predicting the disposition of disturbed substrate materials during the dredging process. Disposal of spoil in the prototype example is on land; however, the mathematical model can, with slight modifications, be programmed to predict the fate of spoil materials dumped within any sector of the related estuarial system.

The fate of suspended sediment in the Bolinas Boat Channel for background tidal sediment and dredging-induced sediment activity is determined. A pseudo-three dimensional model of the hydrodynamics of the estuarial system is operated with tidal stage input for three tidal cycles with suspended sediment input for an eight-hour, working dredge. The hydraulics of the boat channel and sedimentation confine the greatest percentage of sediment to the boat channel and a positive seaward flushing action of the ebbtide transports large quantities of sediment to the mouth of the Bolinas Lagoon and thence to Bolinas Bay. A separate computer run was made assuming dredging in a more hydraulically active channel of the lagoon system. The model predicted more dispersion of the sediment throughout the lagoon than for the boat channel alternative. Benthic inventories for the two dredging locations indicated that greater environmental damage would occur from dredging in the hydraulically active channel.

STUMPF, R. P. 1983. "The Process of Sedimentation on the Surface of a Salt Marsh," Estuarine, Coastal and Shelf Science, Vol 17, pp 495-508.

An unditched salt marsh-creek drainage basin (Holland Glade Marsh, Lewes, Delaware) has a sedimentation rate of 0.5 cm $year^{-1}$. During normal, storm-free conditions, the creek carries negligible amounts of sand and coarse silt. Of the material in the waters flooding the marsh surface, over 80 percent disappears from the floodwaters within 12 m of the creek. About one-half of the lost material is theoretically too fine to settle, even if flow were not turbulent; however, sediment found on *Spartina* stems can account for the loss.

The quantity of suspended sediment that does reach the back marsh during these normal tides is inadequate to maintain the marsh surface against local sea-level rise. This suspended sediment is also much finer than the deposited sediments. Additionally, remote sections of low marsh, sections flooded by only the highest spring tides, have 15 to 30 cm of highly inorganic marsh muds.

This evidence indicates that normal tidal flooding does not produce sedimentation in Holland Glade. Study of the effects of two severe storms, of a frequency of once per year, suggests that such storms can deposit sufficient sediment to maintain the marsh.

The actual deposition of fine-grained sediments (fine silt and clay) appears to result primarily from biological trapping rather than from settling. In addition, this study proposes that the total sedimentation on mature marshes results from a balance between tidal and storm sedimentation. Storms will control sediment supply and movement on micro- and meso-tidal marshes, and will have less influence on macro-tidal marshes.

SUMER, B. M. 1977 (Nov). "Settlement of Solid Particles in Open-Channel Flow," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 103, No. HY11, pp 1323-1337.

Settlement of solid particles in turbulent water environment is encountered in various fields of engineering. Settling basins of hydro-power plants or settling tanks of water treatment plants serve as units for removing suspended solid particles, where the solid particles settle out of suspension due to gravity. When a small heavy particle is released into a turbulent open-channel flow, it moves in the vertical direction under the combined action of: (a) gravity and (b) vertical component of turbulence. If the former is dominant, the particle will finally settle out of suspension.

The particle settlement problem has long been attacked by investigators employing various approaches. Dobbins, in his classical work, approached the problem in the Eulerian sense. Employing the equation of conservation of mass, he obtained a solution for the case of a turbulent tank in which the longitudinal concentration gradient is zero and the turbulent diffusion coefficient is constant. Recently, Bayazit and Li and Shen approached the problem in the Lagrangian sense, simulating the process on a computer. In both studies, employing high-speed digital computers, the path of a marked particle, which was initially at the water surface, was followed as it was settling through statistical field variables. Many such paths were used to predict the statistical properties of the settling length of particles by ensemble averages.

Sayre formulated the dispersion process of sediment particles in an open-channel flow in two differential equations (one for particles suspended in the flow and the other for those deposited on the bed) in the Eulerian sense, permitting the exchange of particles between the bed and the flow. Sayre then obtained zeroth, first, second, and third moments of the concentration numerically using the Aris moment transformations. This made it possible for Sayre to predict important quantities to describe the process in the Lagrangian sense. In an earlier study, which had the purpose of describing the longitudinal dispersion process of small heavy particles, Sumer was able to obtain analytical solutions to the moment equations.

The present paper employs the same analytical technique in analyzing the particle settlement problem.

SUMER, B. M. 1971. "Turbulent Dispersion of Suspended Matters in a Broad Open Channel," Proceedings, Fourteenth Congress of the International Association for Hydraulic Research, Vol 1, Paper A5, pp 33-44.

The mathematical model developed by Sayre for transportation and dispersion of suspended matters (silt or fine sand particles) injected in an open channel flow is taken as the basic model. Several specific cases are expressed as the coefficients of α and γ take the values of zero and one. Here α and γ are the coefficients appearing in the mathematical model of Sayre, called bed-absorbency coefficient and entrainment-rate coefficient, respectively.

In the case of $\alpha = 0$, $\gamma = 0$, the total amount of matter injected to the flow is transported as a suspension. In this study this case is treated. In such a case, it is argued that a characteristic parameter ζ that appears in the dimensionless form of the basic equation is $\ll 1$. In fact, the case of $\zeta \ll 1$ corresponds to the transportation of silt particles as suspended matter in the plain stresses.

Following the basic mathematical model, it is shown that in asymptotic case (as $t \rightarrow \infty$) the dispersion of suspended matters is characterized by a one-dimensional diffusion equation with a certain longitudinal diffusivity written with respect to an axis moving with the mean flow velocity. Later, using the perturbation technique, the longitudinal dispersion coefficient is computed as a series expansion of ζ .

SUMMERS, L. 1975 (Sep). "Dredging in Alluvial Muds," First International Symposium on Dredging Technology, Paper E1, pp 1-12, Canterbury, England.

Many rivers, especially the bigger tropical ones, carry large quantities of sediment which are deposited as bars across the outer limits of estuaries. The sediments typically vary from coarse silts to clay particles which are precipitated by flocculation in the saltwater wedge, in areas of reduced velocities within the estuaries.

To enable shipping to reach ports within the estuary of such a river it is often necessary to realign, deepen, and stabilize the natural channel across the bar by means of dredging. However, in soft, silty muds it is difficult to meet the demand for increasing depths and widths of access channels, and a correct understanding of the nature and condition of such material is necessary in order to achieve a reliable navigation channel.

These problems were encountered in a study of dredging of the navigation channel across the bar at the mouth of the River Chao Phraya with the object of developing methods of improving the approaches to the Port of Bangkok. Considerable quantities of new sediments are deposited annually and existing siltation is redistributed by storm action in the estuary. Special methods were evolved to obtain information on the variation of in situ soil density with depth, using gravity samplers some 2 m in length and a densimeter with a radioactive source. Variations in density depend upon the history of dredging and deposition in the area sampled. The studies showed that the most economic dredging should be considered in terms of the volume of silt removed from within the desired channel profile and not, as might have been expected, by obtaining maximum hopper loading from the more consolidated muds and clays. An optimum relationship between in situ density, hopper density of spoil, and length of dredging cycle time was evolved.

The conclusion is drawn that, with such a major task of maintenance dredging in fresh alluvial muds, there was a need for a total system specifically designed for the particular channel. Factors to be considered in relation to the spoil to be handled are derived in the paper.

SUNDERMANN, J., and VOLLMERS, H. 1972 (Nov). "Tidal Waves in Estuaries," Wasserwirtschaft, Vol 62, No. 11, pp 333-341.

A systematical comparison between experiments in hydraulic models and hydrodynamical-numerical computations for the case of the propagation of tidal waves in schematical estuaries is carried out. It is the aim of the investigations to present clearly the advantages and disadvantages of the two models.

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TAIGBENU, A. E., LIGGETT, J. A., and CHENG, A. H. 1984 (Aug). "Boundary Integral Solution to Seawater Intrusion into Coastal Aquifers," Water Resources Research, Vol 20, No. 8, pp 1150-1158.

The boundary integral equation method is used to solve problems of seawater intrusion into a freshwater aquifer that is being pumped. The transient problem of intrusion (lens type) into a deep aquifer is solved, as is the steady-state problem of intrusion (wedge type) into a shallow aquifer. Both cases are compared with analytical solutions that are available for simple geometries. The numerical models uses the Dupuit-Forchheimer approximation to reduce the three-dimensional problem to two dimensions. It then used the Ghyben-Herzberg approximation, which simplifies the treatment of flow in the saltwater region. A "special potential" eliminates the need to track explicitly the freshwater-saltwater interface. The numerical program adds to the capability of the general groundwater basin model, which was based on the same techniques.

TAIRA, A., and SCHOLLE, P. A. 1979 (Sep). "Discrimination of Depositional Environments Using Settling Tube Data," Journal of Sedimentary Petrology, Vol 49, No. 3, pp 787-800.

The settling-velocity distributions of more than 500 modern and near-modern river, dune, beach, tidal-flat, and turbidite sediment samples were analyzed using a photo-extinction settling tube. Discriminant function analysis was applied in order to investigate the possibility of extracting environmental information from settling velocity distributions using 65 variables that describe distribution curves. The results showed that (a) good discriminations were obtained between reference sets of river, beach, and dune sediments; (b) reliable answers were obtained through identification tests of "unknown sets" using reference sets; (c) the Triassic and Jurassic Navajo Sandstone samples were mostly grouped as eolian (dune) when compared with the analyzed sets of samples; and (d) the variables useful for environmental discrimination were chiefly related to the tails of distributions. Some variables commonly used for environmental analysis were found to be more influenced by provenance factors than by environmental factors.

TAKAMATSU, T., NAITO, M., SHIBA, S., and UEDA, Y. 1974 (Aug). "Effects of Deposit Resuspension on Settling Basin," Journal, Environmental Engineering Division, American Society of Civil Engineers, Vol 100, No. EE4, pp 883-903.

The demand for water has greatly increased while the available amount of water is limited. As a result water and wastewater treatment plants have to be designed or operated to attain higher efficiencies. This paper is concerned with (a) establishing a mathematical model to evaluate effects of resuspension of deposit on the removal efficiency of a sedimentation basin; and (b) predicting the most desirable depth of the basin based on the proposed mathematical model.

TAMBO, N., and HOZUMI, H. 1979a. "Physical Aspect of Flocculation Process--II. Contact Flocculation," Water Research, Vol 13, pp 441-448.

Kinetic equations which describe the process of contact flocculation in solids contact clarifiers were proposed. Decrease of micro-flocs with the contact of high-concentration and large-diameter well-grown flocs both in a turbulent flocculation chamber and in a floc blanket of upflow clarifier were discussed.

First order equations with the micro-floc concentration were derived theoretically for both types of contact flocculation. By experiments, these kinetic equations were verified and their coefficients were evaluated.

Finally, practical equations for the design of micro-floc removal process with contact of well-grown-flocs both in a turbulent flocculator and in a floc blanket were proposed.

TAMBO, N., and HOZUMI, H. 1979b. "Physical Characteristics of Flocs--II. Strength of Floc," <u>Water Research,</u> Vol 13, pp 421-427.

Characteristic features of floc strength were examined by theoretical and experimental studies by using clay-aluminum flocs. It is the purpose of the authors to develop theoretical and experimental methods to evaluate maximum floc size under an agitation condition and to give a function of floc strength for the rational design of flocculation and sedimentation process.

TAMBO, N., and WATANABE, Y. 1979a. "Physical Aspect of Flocculation Process--I. Fundamental Treatise," Water Research, Vol 13, pp 429-439.

A dimensionless equation for the floc growth operation was developed and simulation of the floc growth operation was carried out to obtain the numerical solutions of the floc growth equation. A comparison of the simulation results with the experimental results suggested that it was necessary to introduce a collision-agglomeration function into the original floc growth equation.

The floc growth equation with the collision-agglomeration function gave simulation results which almost coincided with the experimental results. The self-preserving nature of floc size distribution was found by using the results of both simulation and experiment. The results of simulation and experiment were shown in the normalized floc size distribution and the normalized removal rate in an ideal sedimentation basin.

TAMBO, N., and WATANABE, Y. 1979b. "Physical Characteristics of Flocs--I. The Floc Density Function and Aluminium Floc," Water Research, Vol 13, pp 409-419.

Some characteristics of floc density were illuminated by experiments and model floc simulation by using clay-aluminum flocs. As an aluminium floc is a very fragile particle, the authors adopted an experimental method in which the settling velocity and diameter of a discrete floc were measured in a quiescent water column. Floc density was calculated by introducing the measured values and some constants such as water density and viscosity into a suitable settling velocity equation. In this study a modified Stokes equation was used.

TASK COMMITTEE ON RELATIONS BETWEEN MORPHOLOGY OF SMALL STREAMS AND SEDIMENT YIELD OF THE COMMITTEE ON SEDIMENTATION OF THE HYDRAULICS DIVISION. 1982 (Nov). "Relationships Between Morphology of Small Streams and Sediment Yield," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 108, No. HY11, pp 1328-1365.

The state of the art in the relations between morphology of small streams and sediment yield is assessed. Research findings and recommendations for additional research are presented. Topics include systems and interactions, simulation models, channel forms and processes, transport of sediment in small streams, and aspects of channel morphology. Selected topics for additional research are also included.

TASK COMMITTEE ON CAUSES AND EFFECTS OF SHOALING IN NAVIGABLE WATERS OF THE COMMITTEE ON WATERWAYS OF THE WATERWAY, PORT, COASTAL, AND OCEAN DIVISION. 1983 (May). "Shoaling Processes in Navigable Waters," Journal of Waterway, Port, Coastal and Ocean Engineering, Vol 109, No. 2, pp 199-221.

Sedimentation processes in our nation's waterways and harbors are controlled by a complex array of physical and chemical factors that are known only in general terms. Evaluation of hydrodynamic processes and identification of null points are the most useful methods in predicting shoaling in navigation channels. Physiochemical processes controlling sedimentation are complex interactions of suspended solids and water chemistry which are in the early stages of infancy in respect to our understanding and interpretation. While significant advances in understanding of sediment transport phenomena have occurred in the last several years, much remains to assemble this information into a coherent fabric that allows it to be applied toward reducing maintenance dredging. Maintenance dredging to sustain navigation channels annually involves removal of more than 350 million cubic yards of shoaling materials in our waterways. This paper presents an integrated view of the shoaling processes.

TEETER, A. M. 1983 (Aug). "Investigations on Atchafalaya Bay Sediments," Proceedings, Frontiers in Hydraulic Engineering Conference, American Society of Civil Engineers, H. T. Shen, ed., pp 85-90, Cambridge, Mass.

The settling and consolidation behavior of bed and suspended sediments were observed under various conditions in laboratory and field experiments. Sediments in the bay are fractionated by differential settling. Settling velocity variation in the bay is a result of this and of local bed resuspension. For a given sediment, concentration and settling height were found to be important factors effecting settling velocity. The sediments have relatively low cohesiveness and are dominated by silts made up of quartz. Bed sediments are subjected to frequent resuspension by tidal currents. Laboratory estimates of the density of newly deposited sediments and numerical results indicate that consolidation is rapid after deposition occurs.

TENNESSEE VALLEY AUTHORITY, et al. 1941 (Nov). "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams, Methods of Analyzing Sediment Samples," Report No. 4, US Engineer District Sub-Office, Hydraulic Laboratory, University of Iowa, Iowa City, Iowa.

A description and discussion of methods of determining particle size, particularly with reference to their adaption to suspended sediment samples, occupies the major portion of this report.

The size determination of fine-grained materials, i.e., particles smaller than about 1/16 mm, is based almost entirely upon fall velocities in a fluid, the relation of fall velocities and fluid properties being interpreted in terms of particle diameters by Stokes' law. Convenient graphical methods for calculating particle diameters from the observed fall velocities and fluid properties are presented for conditions where Stokes' law does and does not apply. The review reveals that the greater number of the present methods are not sufficiently sensitive and accurate for analyzing suspended sediment samples of very low concentrations. The need for development of rapid, accurate, and reliable methods adaptable to mass analysis of suspended sediment samples is apparent.

Although sieving has been the common method for analyzing coarse sediments, a number of hydraulic separation methods have been devised that appear promising. Further development of these settling rate methods is needed in this country, for, as emphasized in the report, a diameter calculated from a fall velocity is generally more valuable in sediment studies than a sieve diameter or a direct physical measurement. The methods of analyzing sediment samples for total solids concentration are also described and discussed; first, as separate independent procedures and then in relation to size analysis methods. Several relatively new methods, advantageous to use with certain types of sediment samples, are presented. Procedures for a number of the more common methods of particle size and total concentration analysis, as used various agencies, are described in detail in the appendix. Applicable standard procedures of the American Society for Testing Materials are indicated.

An extensive bibliography is given, classified by subjects as well as by authors, in alphabetical order.

TENNESSEE VALLEY AUTHORITY, et al. 1943 (Jun). "A Study of Methods Used in Measurement and Analysis of Sediment Loads in Streams, A Study of New Methods for Size Analysis of Suspended Sediment Samples," Report No. 7, US Engineer District Sub-Office, Hydraulic Laboratory, Iowa City, Iowa.

In Report No. 4 of this series, "Methods of Analyzing Sediment Samples," a study of available literature on methods of determining the sizes of sediment particles was described. It was concluded that none of the present methods for analyzing suspended sediment samples can be applied satisfactorily to all sizes and concentrations which are encountered in flowing streams. The present study was undertaken in an attempt to supply this deficiency. The bottom withdrawal tube developed in the course of this study appears to meet the need. This device is a glass tube, 50 to 100 cm in length, equipped with a volumetric scale and a quick-acting outlet at the lower end. First the sample is uniformly dispersed in the tube. Then the tube is placed in an upright position and samples of known volume are drawn from the bottom at known time intervals. When the sediment weight in each fraction has been determined, the particle size distribution can be computed with the aid of a so-called Odén curve.

The report includes a review of the range of conditions for which the present methods of size analysis are suitable. The various devices investigated and the method of computing the size analysis of sediments on the basis of a uniform dispersion of particles are described. The modification of this method for application to data obtained with the bottom withdrawal tube is explained. A description of the tests made to determine the accuracy and range of applicability of the apparatus is also included.

TERWINDT, J. H. J. 1977. "Deposition, Transportation and Erosion of Mud," Proceedings of the International Symposium, H. L. Gofterman, ed., pp 19-24.

Flocculation affects the fall velocity of the mud and the rate of deposition, especially in flowing water having bed shear stresses below a certain critical value. In the latter case finally all suspended sediment will settle down. In flowing water which exhibits bed shear stresses above the critical value, the rate of deposition is determined by the initial concentration in the fluid. In a steady state there is an equilibrium mud concentration which remains in suspension for a given value of the bed shear stress.

Deposited mud undergoes a relatively rapid initial consolidation which results in an increasing shear strength of the mudlayer. So in time there is an increase in the critical bed shear stress necessary to initiate erosion of the mudlayer. The value of this critical bed shear stress and the rate of erosion largely depends on the chemical state of the particles and the surrounding fluid.

TERWINDT, J. H. J., BRUESERS, H. N. C., and SVASEK, J. N. 1968. "Experimental Investigation on the Erosion-Sensitivity of a Sand-Clay Lamination," Sedimentology, Vol 11, pp 105-144.

This report describes an investigation by means of laboratory tests of the critical shear stress and bed erosion as a function of time and bed shear stress for sediment consisting of alternating sand and clay layers 0.1 to 3 cm thick. This type of deposit occurs quite frequently in estuaries and tidal inlets. The tests were carried out on an original bed deposited in an estuary.

The critical shear stress and the degree of erosion in relation to time for the sand-clay lamination were found to agree in order of magnitude with those for clay layers. The resistance to erosion of the sand-clay lamination is therefore comparable with that of clay layers.

THIMAKORN, P. 1980 (Mar). "An Experiment on Clay Suspension Under Water Waves," Proceedings, Seventeenth Coastal Engineering Conference, American Society of Civil Engineers, Vol III, Chapter 174, pp 2894-2906.

The physical behavior of water waves upon the suspension of fine cohesive clay was explored experimentally in a wave channel. Results obtained from the experiment show that equilibrium concentration is reached in the wave field some time about five hours after the initiation of waves. The ratio between the mean bottom concentration and the vertical average is constant and yields almost the same value within the range 1.17 and 1.34 at equilibrium, and the bottom concentration at equilibrium is linearly proportioning to the maximum bottom velocity of waves. The dimensionless transient concentration possesses a relationship also with the bottom velocity, and the bottom shear stress can be related to the maximum value of the ratio between the bottom concentration and the vertical average value found within a short time after the initiation of waves.

THOMAS, D. G. 1965. "Transport Characteristics of Suspension: VIII. A Note on the Viscosity of Newtonian Suspensions of Uniform Spherical Particles," Journal of Colloid Science, Vol 20, pp 267-277.

A critical analysis was made of the extensive experimental data on the relative viscosity of suspensions of uniform spherical particles. By appropriate extrapolation techniques, non-Newtonian, inertial, and nonhomogeneous suspension effects were minimized. As a result, the scatter of the data was reduced from ± 75 percent to ± 13 percent at a volume fraction solids of 0.50. The coefficients of different power series relating relative viscosity and volume fraction solids were determined using a nonlinear least squares procedure. It was shown that a new expression containing three terms of a power series with coefficients determined from previous theoretical analyses and an exponential term with two adjustable constants fit the data as well as a power series with six terms, either three or four of which were adjustable constants with the remaining coefficients being theoretical values.

THOMPSON, R. W. 1975. "Tidal-Flat Sediments of the Colorado River Delta, Northwestern Gulf of California," Tidal Deposits, R. N. Ginsburg, ed., Section I, Chapter 7, pp 57-65, Springer-Verlag, New York.

A model of sedimentary facies expected from tidal-flat deposition was proposed recently by Klein for purposes of recognizing ancient tidal-flat deposits and estimating paleotidal range. Information concerning components of this model has come largely from tidal flats that have accumulated in temperate regions in either the lee of large barrier islands or protected coastal embayments. In these circumstances, restriction of tidal access to and from the tidal flats yields substantial currents and the development of elaborate tidal channel systems that largely control the sedimentation patterns. Furthermore, substantial sand is transported to the tidal flats under the combined influence of littoral drift and tidal currents.

The resulting tidal-flat deposits are predominantly sand and show a distinct upward-fining in texture through three main facies: (a) well-cross-bedded and cross-laminated sand at the base (subtidal); (b) interlaminated sand and mud in the middle (intertidal); (c) organic-rich clay or peat at the top (supratidal). The sediments are generally dark gray-black and the remains and traces or organisms are conspicuous throughout. Evaporites are negligible in the sequence. In the geologic record, such deposits might be anticipated in a stratigraphic complex of interbedded lenticular sandstones, dark gray shales or mudstones, and coals that accumulated in associated barrier island, shallow neritic, and deltaic environments.

With only this image of tidal-flat deposits, recognition of ancient analogs of the gulf tidal flats in the geologic record would be improbable. Little sand has reached these tidal flats because of the tidal circulation system, and this, combined with low wave energy and copious supply of silt and clay, has resulted in insignificant barrier development. Tidal currents therefore are little restricted and move over the flats as a broad uniform flow with little tendency to develop channel systems. Suspension-deposited silty clays occur in the subtidal and lower intertidal zones rather than cross-bedded sands. Typically uniform horizontal lamination and bedding occur on the intertidal flats rather than lenticular (wavy) or flaser bedding. Silt and clay predominate and upward-fining of texture does not occur.

ιN, M. F. C. 1982. "Physical Processes of Siltation in Tidal Channels," ·aulic Modelling in Maritime Engineering, Chapter 6, pp 65-78, Thomas ·ord Ltd, London, England.

The prediction of siltation in tidal channels through physical or mathe- ical modeling needs equations relating sediment movement to water movement. ·arch has established forms of relationship to describe the physical pro- ·es in both muddy and sandy estuaries, but they contain empirical coeffi- ·ts that must be determined for each site studied. Field and laboratory ·stigations are therefore an essential part of any engineering study and ·iction of channel siltation. With this restriction, it is possible to ·te a computational framework based on sound theoretical principles from ·h siltation predictions can be made with some confidence.

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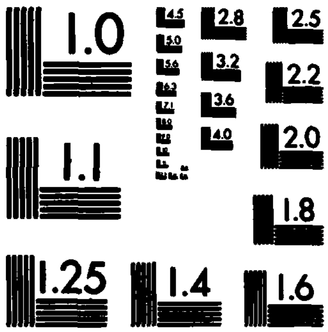

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THORN, M. F. C., and PARSONS, J. G. 1980 (Mar). "Erosion of Cohesive Sediments in Estuaries: An Engineering Guide," Proceedings, Third International Symposium on Dredging Technology, Paper F1, pp 349-358, Bordeaux, France.

The prediction of siltation in navigation channels dredged in cohesive sediments and of the mobility of cohesive dredged spoil at a disposal ground requires a knowledge of the erosion properties of the sediments. The Hydraulics Research Station has recently carried out project studies of the properties of three different cohesive muds using the same experimental and analytical techniques. The results show qualitative and quantitative similarities in their physical properties and behavior, despite differences in their particle size distribution and mineralogical composition. This paper presents and compares the results of bed consolidation and erosion tests on the three muds and concludes that it is possible to deduce quantitative relationships for the erodibility of cohesive sediments that might be applied in preliminary design studies of engineering schemes involving similar cohesive sediments. The framework of laboratory investigation and analysis may be used to determine the specific erosion characteristics of a particular sediment for the purpose of detailed prediction and design calculations.

THORNTON, I., WATLING, H., and DARRACOTT, A. 1975. "Geochemical Studies in Several Rivers and Estuaries Used for Oyster Rearing," The Science of the Total Environment, Vol 4, No. 4, p 325-345.

Base-line studies have been carried out on the trace metal content of bottom sediments and waters of five estuaries and their catchment drainage, representing both contaminated and relatively uncontaminated environments. Relationships have been established between the composition of water and sediments in tributary drainage and those in the estuary. In particular, regional contamination of the hinterland with one or more of the elements As, Cd, Cu, Pb, Zn, and Sn from mining and smelting activity was reflected by enhancement in estuarine muds in relation to the proportion of the catchment affected and the degree of contamination. Preliminary observations on young oysters showed that in general metal accumulation reflected the geochemical status of the estuary. These investigations have confirmed the potential use of geochemical reconnaissance maps based on stream sediment analysis as a means of focussing attention on rivers and estuaries affected by regional metal pollution.

TOOBY, P. F., WICK, G. L., and ISAACS, J. D. 1977 (May). "The Motion of a Small Sphere in a Rotating Velocity Field: A Possible Mechanism for Suspending Particles in Turbulence," Journal of Geophysical Research, Vol 82, No. 15, pp 2096-2100.

The diffusion and transport of particles suspended in turbulent flows depend on the interaction between the particles and the turbulence. To investigate a possible particle-turbulence interaction, the authors observed particle trajectories in a rotating fluid with a solid body velocity profile, as might occur in the core of a vortex or an eddy. The experiments were conducted with a series of single small spheres (with low particle Reynolds numbers) sinking or rising in a horizontal cylinder rotating about its central axis at a constant speed. Each sphere was found to follow a nearly circular orbit in a vertical plane perpendicular to the cylinder axis. The orbit center lay very near the horizontal plane through the axis of the cylinder and was at the point in the fluid where the velocity of the fluid was equal and opposite to the terminal velocity of the particle. The particle trajectories also evolved slowly, spiraling either inward or outward. A theoretical description of the particle motion shows that the two principal forces on the particle fluid drag and gravity-buoyancy account for the circular motion. A force due to particle inertia (a centrifugal force from the center of its orbit), a small position-dependent wall effect on drag, a very small force (also affected by the walls), and a very small centrifugal buoyancy force account for the long-term inward or outward spirals. This kind of systematic interaction in which particles seek and remain in fluid closely opposing their own motion could have a role in the suspension of small particles in some turbulent flows.

TRAWLE, M. J. 1982 (Mar). "Salinity and Sedimentation Estimates for Proposed Savannah Harbor Deepening," WESHE Letter, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

A reasonable estimate of the changes in salinity to be expected if the navigation channel is deepened to 46 ft is presented. If this estimate is reasonably accurate, the information presents reasonable estimates of the changes in salinity to be expected from depth increases to 42 or 44 ft. WES believes that depth increases of 42, 44, or 46 ft would have little impact on total maintenance dredging requirements, but further upstream shifts in the location of the major shoaling area can be expected with each incremental increase in channel depth.

TUBMAN, M. W., and SUHAYDA, J. N. 1977. "Wave Action and Bottom Movements in Fine Sediments," Proceedings, Fifteenth Coastal Engineering Conference, Vol II, Chapter 69, pp 1168-1183.

Mudbanks have been observed to have an extraordinary calming effect on the sea surface. In certain cases this effect is due primarily to the transfer of energy through the sea/mud interface and its frictional dissipation within the bottom sediments. This paper describes an experiment that measured wave characteristics and the resulting sea floor oscillations in an area where the bottom is composed of fine-grained sediments. The energy lost by the waves at the position of the experimental setup is calculated and compared with a direct measurement of the net energy lost by the waves in going from the point of the experiment to a station 3.35 km inshore. Results show that bottom motions in the range of wave-induced bottom pressures from near zero to 2.39×10^3 Pascal have the appearance of forced waves on an elastic half space. The apparent effect of internal viscosity is seen in a phase shift between the crest of the pressure wave and the trough of the mud wave. Measurements show this angle to be 22° (±11°) for the peak spectral component ($T = 7.75$ seconds). The energy lost to the bottom by the waves at the field site was found to be at least an order of magnitude greater than that resulting from the processes of percolation or that caused by normal frictional effects. This newly observed mechanism for the dissipation of wave energy i. particularly important for waves in intermediate-depth water and could be a prime factor in determining design wave heights in muddy coastal areas.

TURNER, J. S. 1973. "Turbulent Shear Flows in a Stratified Fluid," Buoyancy Effects in Fluids, Chapter 5, pp 127-164, University Printing House, Cambridge, Mass.

The theme of this chapter will be a more detailed discussion of various kinds of turbulent shear flows, which are well past the state of marginal stability. Some knowledge of the properties of a turbulent shear flow in a homogeneous fluid must be assumed and we consider here the additional effects introduced by the presence of density gradients. Turbulent flows in which gravity plays an essential role in driving the mean motion will be treated separately.

These flows will be discussed against the background emphasizing the turbulent features, but also referring to the wave aspects when necessary. It was considered first a shear flow near a horizontal boundary, and the effect of a vertical density gradient on the velocity and density profiles, and on the rates of transport. Next it was discussed that the few theoretical results which are available to describe 'boundary' and 'interior' turbulence in stratified shear flows. Finally, it was presented and discussed laboratory and larger scale observations which can be used to test these ideas.

U

UMEHARA, Y., and ZEN, K. 1982 (Mar). "Consolidation and Settling Characteristics of Very Soft Contaminated Sediments," Proceedings, 6th US/Japan Experts Meeting, US Army Corps of Engineers, Water Resources Support Center, pp 169-194.

With respect to the dredging and reclamation for the management of contaminated sediments, information on mechanical properties of very soft soils is normally required, although the determinations involve technical difficulties. A new method to determine the consolidation constants for very soft soils has previously been proposed. Using this method and sedimentation test methods, the consolidation and settling characteristics of contaminated sediments taken from several harbors in Japan were investigated.

The proposed method is briefly described, and its validity is verified by analyzing the self-weight consolidation phenomena of a model fill composed of contaminated sediments. Test results on other sediments are also presented and comparatively examined.

UNKNOWN AUTHOR. 1971 (Feb). "Water and Sediment Control," Dock & Harbour Authority, Vol 604, pp 421-423.

Arising from its development and use as a wind-break material, plastic netting can now be used as a means of controlling water-borne sediment. Experimental work has established the fact that netting of between 40 and 50 percent permeability is highly effective as a means of wind protection. Also, it was found possible to cause dunes to build up in the lee of windbreaks where winds caused sand shift.

Subsequently, when considering the problem of controlling scour in the tributaries of a large dam to reduce siltation, thereby extending the dam's working life, it was thought that underwater fences made of permeable material might be used to cause sedimentation in the tributaries before they discharged to the dam.

This solution raised the possibility of wider application of the netting in the water and hydraulic engineering. It was therefore decided to commission independent testing of the principle by a recognized authority on hydraulic matters, and early last year the Ministry of Technology Hydraulic Research Station at Wallingford was invited to study the effects of the proposed underwater fences on sediment movement.

The fences comprise curtains of plastic net stretched between bed anchors along the lower edge and supported by buoyancy elements along the upper. In theory, the fences are intended to obstruct the movement of water close to the bed reducing its velocity, redistributing flow, and absorbing energy. Reduction of velocity near the bed reduces the sediment-carrying potential of the water and therefore the amount of solid material transported.

Tests were performed on three possible applications of the technique. The first, using the fences as a submerged off-shore breakwater, attempted to attenuate waves impinging on a model beach, thus protecting it against erosion.

Further tests in the same channel indicated that a configuration of fences could be devised to reduce or eliminate seabed scour caused by change of water velocity in the immediate vicinity of structures such as piles or piers.

The third test series dealt with movement of bed material in undirectional flow, for example in a river or an estuary near the sea in which wave action is negligible but tidal or other currents flow in one direction for long periods.

US ARMY ENGINEER DISTRICT, CHARLESTON. 1964 (May). "Shoaling Study, Georgetown Harbor, South Carolina," Charleston, S.C.

The purpose of this report is to present the results of investigations to determine the engineering and economic feasibility of plans directed toward development of possible methods to reduce shoaling and consequent maintenance dredging in Georgetown Harbor. Inherent in the purpose and scope is the duty to consider whether plans of improvement showing substantial promise should be subjected to investigation by hydraulic model tests to further corroborate the engineering and economic feasibility of such plans.

US ARMY ENGINEER DISTRICT, PHILADELPHIA. 1948 (May). "Report on the Effect of the North Jetty Extension on Shoaling in the Eastern Entrance to the Chesapeake and Delaware Canal," Philadelphia, Penn.

The results of this study, based on all available data to date, indicate that the amount of shoaling in the eastern entrance to the Chesapeake and Delaware Canal has not changed since the construction of the extension to the north jetty. But it is important to note that the data on shoaling in the 27-foot canal covers only three years before the jetty was extended and revealed rates which vary considerably. The period after the extension also covers only three years, and while it had shoaling rates in the channel which were consistent within themselves, they do not include any extremely low rates as did the former period. Therefore, it is desirable to defer any final conclusion until at least two additional shoaling seasons have passed in order that the mean shoaling rate for the period after the construction of the extension can be established more conclusively.

US ARMY ENGINEER DISTRICT, SAN FRANCISCO. 1974 (Jun). "Dredge Disposal Study, San Francisco Bay and Estuary; Appendix A, Main Ship Channel (San Francisco Bar)," San Francisco, Calif.

The study program included sampling, testing, and analyzing the physical, biological, and chemical properties of the main ship channel and disposal sites on the bar and the determination of the material dispersion and deposition pattern during the release operations.

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION. 1953 (Feb). "Plans for Elimination of Shoaling in the Vicinity of Head of Passes, Mississippi River; Hydraulic Model Investigation," Technical Memorandum No. 2-356, Vicksburg, Miss.

The Head of Passes model study was conducted for the purpose of determining the most economical and effective plan for the elimination or reduction of shoaling in the Mississippi River near the Head of Passes.

A movable-bed-type model, constructed to linear-scale ratios of 1:500 horizontally and 1:150 vertically, reproduced seven miles of the Mississippi River above the Head of Passes, all of South and Southwest Passes, the upper two miles of Pass a Loutre, and the upper one-half mile of Cubits Gap. Cubits Gap and Pass a Loutre were each controlled to discharge a fixed proportion of the flow, while the discharges in South and Southwest Passes were controlled by maintaining the water-surface elevation at their lower ends to mean gulf level.

The testing program was divided into three phases: (a) discharge-distribution tests; (b) verification of the model; and (c) tests of proposed improvement plans. The discharge-distribution tests consisted of preliminary tests to determine the effects of various proposed improvement works upon distribution of discharge among the passes. Tests were also conducted to determine the effects of contraction works constructed in Southwest Pass and of the dredge cut (then in progress) in that pass from mile 10.5 to the gulf upon the discharge distribution. Verification tests were conducted after the model had been adjusted to establish hydraulic operating conditions. These tests reproduced accurately the changes in bed configuration which occurred in the prototype during the period between the 1937 and 1939 prototype surveys. The tests of improvement plans consisted of a base test and tests of 27 plans tentatively proposed for the improvement of the channel in the vicinity of Head of Passes.

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION. 1949 (May). "Plans for Reduction of Shoaling at the Entrance to Umpqua River, Oregon; Model Investigation," Technical Memorandum No. 2-277, Vicksburg, Miss.

It is the opinion of the Waterways Experiment Station that the results of tests presented herein are largely qualitative and do not show conclusively that any one of the plans tested would solve the shoaling problems in the entrance channel. Based upon the effects of the various plans on current directions and velocities, it is believed that plan 1-A would be the most effective of the plans tested in reducing shoaling in the channel. It is also believed that extension of the plan 1-A jetty seaward would make the structure more effective; however, such extension would probably increase the cost of the jetty appreciably, since relatively deep water would be encountered a short distance beyond the outer end of the structure as tested in the model.

A study of the results of the model test of plan 1-A indicated that consideration should be given to testing the following two additional jetty plans in the model: (a) a plan similar to plan 1-A except that the proposed south jetty would be exactly parallel to the existing north jetty, the distance between these two jetties to be the same as the distance from the north jetty to the shore end of the plan 1-A south jetty; and (b) a test of the above proposed plan with the proposed south jetty extended 1000 ft seaward, still parallel to the existing north jetty. It is believed that the curvature of either of these proposed jetties would be such as to deflect ebb currents more nearly into alignment with the navigation channel than did the plan 1-A jetty.

US ARMY ENGINEER WATERWAYS EXPERIMENT STATION. 1959 (Jul). "Summary of Best Plans for Reducing Shoaling, Southwest Pass, Mississippi River; Hydraulic Model Investigation," Miscellaneous Paper No. 2-349, Vicksburg, Miss.

From a purely technical viewpoint, it appears that plan 17A would be the most effective of the plans tested for reducing shoaling at the entrance to Southwest Pass. The reductions in shoaling indicated by the phase 4 tests of plan 14K are not significantly less than those indicated by the phase 5 tests of plan 17A for test 3 and test 4 conditions; however, the full benefits indicated for plan 14K will only be realized when and if the cross-sectional area of the pass with the plan installed is restored to that which now exists for the present channel. On the other hand, the benefits indicated for plan 17A are immediate benefits, and any reduction in cross-sectional area subsequent to construction of this plan would increase its effectiveness.

V

VALIOULIS, I. A., LIST, E. J., and PEARSON, H. J. 1984 (Jun). "Monte Carlo Simulation of Coagulation in Discrete Particle-Size Distributions, Part 2. Interparticle Forces and the Quasi-Stationary Equilibrium Hypothesis," Journal of Fluid Mechanics, Vol 143, pp 387-411.

Hunt and Friedlander used dimensional analysis to derive expressions for the steady-state particle-size distribution in aerosols and hydrosols. Their results were supported by thy Monte Carlo simulation of a noninteracting coagulating population of suspended spherical particles developed by Pearson, Valioulis, and List. Here the realism of the Monte Carlo simulation is improved by accounting for the modification to the coagulation rate caused by van der Waals', electrostatic and hydrodynamic forces acting between particles. The results indicate that the major hypothesis underlying the dimensional reasoning, that is, collisions between particles of similar size are most important in determining the shape of the particle-size distribution, is valid only for shear-induced coagulation. It is shown that dimensional analysis cannot, in general, be used to predict equilibrium particle-size distributions, mainly because of the strong dependence of the interparticle force on the absolute and relative size of the interacting particles.

VanDORN, W. G., INMAN, D. L., and HARRIS, R. W. 1975 (Nov). "The Evaluation of Sediment Management Procedures, Phase I Final Report, 1974-1975," Proposal UCSD 0147, University of California, Scripps Institution of Oceanography, LaJolla, Calif.

This is the final report for Phase I of a continuing investigation of low-cost alternative solutions to present dredging practice at Navy facilities, the costs of which have risen factorially in recent years. Although the overall program is aimed at a general categorization of Navy sedimentation problems and possible solutions, the seven-month duration of Phase I restricted efforts to more specific objectives in the San Francisco Bay area.

After a literature search and discussions with authorities on dredging and sedimentation problems, site visits were made to Naval Weapons Station at Concord, Naval Air Station at Alameda, and Naval Shipyard at Mare Island. The latter facility was selected as having the greatest potential for quantitative analysis and short-term development of specific remedial procedures.

Sediment analyses showed that, owing to its cohesive and rapid compacting properties, only prevention of initial deposition or frequent removal offered hope of reducing dredging requirements. Both methods of approach were investigated by a series of laboratory tests.

Van RIJN, L. C. 1980 (Nov). "The Measurement of Sediment Concentrations in Tidal Conditions," Publication No. 244, 19th IAHR-Congress, New Delhi, India.

Accurate predictions for morphological problems in rivers and estuaries can only be made if the relationship between the local sediment transport and flow conditions is known. In general this knowledge cannot be obtained with sufficient accuracy from transport formulas only. On the contrary, high priority should always be given to field measurements.

In tidal conditions the use of bottle-type samplers is not only impractical because of the handling of a large number of bottles but also not reliable in a statistical sense because of the short sampling times.

Modern instruments like optical and acoustical samplers may also be considered. A major drawback of these instruments, however, is the size-dependent calibration. Consequently, in tidal conditions a large number of water samples is still needed for calibration purposes. It is concluded that in tidal conditions a method is required which enables the sampling and handling of a large volume of water (say 50 liters) to obtain a reliable average value of the concentration. A pump sampler in combination with an instrument of the in-situ separation of water and sediment will satisfy these requirements. Separations methods which can be used, are: the sedimentation method, the filter method, the hydro-cyclone method, and the centrifuge method.

This paper evaluates the pump-sampling method and the in-situ separation methods.

VELDE, B. 1977. "Clays and Clay Minerals in Natural and Synthetic Systems," Developments in Sedimentology, Vol 21, Elsevier Scientific Publishing Co., New York.

This section has attempted to outline the principles which can be used to analyze the equilibria which determine clay mineral assemblages in the various geological environments. Due to the limitations of laboratory techniques, little use can at present be made of theoretical (calculable) thermodynamic variables controlling mineral equilibria. Heaviest reliance is placed upon natural occurrence and laboratory equilibrium studies. This is a method currently practiced with great success in the study of metamorphic and igneous rocks which finds a logical application in the field of clay mineralogy. Many of the results of such reasoning will be only approximate, mainly due to imperfect knowledge of natural occurrences and/or as yet unattempted studies of appropriate synthetic systems which approximate natural clay mineral assemblages. However, it is hoped the initiation of such a procedure will lead to completed knowledge and eventually to the solution of the major enigmas of clay mineralogical studies.

VELTMAN, M. 1979. "Disposal of Contaminated Estuarial Sediment," Presented at First International Conference on Cohesive Sediments, Cambridge, England.

The author endeavored pointed out some aspects of the difficulties caused by pollution of the mud in our ports. The entire problem is being studied nowadays, because of the great importance attached to it. Yet it must be borne in mind that only the first steps have been made. The present state of our knowledge does not warrant drawing conclusions. It will be several years before we know what the long-term effects are.

For the moment there is no time for complete freedom of research: a concerted and coordinated approach is needed.

The ports of Rotterdam are being contaminated as a result of the over-populated and industrialized condition of the River Rhine. Even if all discharges of polluted waste were banned this very moment, the mud in the ports would continue to become polluted for the next ten to twenty years. Problems do not solve themselves.

VISHER, G. S. 1969 (Sep). "Grain Size Distributions and Depositional Processes," Journal of Sedimentary Petrology, Vol 39, No. 3, pp 1074-1106.

Extensive textural study of both modern and ancient sands has provided the basis for a genetic interpretation of sand texture. Analysis is based on recognizing sub-populations within individual log-normal grain size distributions. Each log-normal sub-population may be related to a different mode of sediment transport and deposition, thus providing a measure of their importance in the genesis of a sand unit. The three modes of transport reflected are (a) suspension, (b) saltation, and (c) surface creep or rolling. Each of these is developed as a separate sub-population within a grain size distribution. The number, amount, size-range, mixing, and sorting of these populations vary systematically in relation to provenance, sedimentary process, and sedimentary dynamics. The analysis of these parameters is the basis for determining the process-response characteristics of individual sand units.

A number of processes are uniquely reflected in log-probability curves of grain size distributions of sands and sandstones. These include: (a) current, (b) swash and backwash, (c) wave, (d) tidal channel, (e) fallout from suspension, (f) turbidity current, and (g) aeolian dune. The combination of two or more of these processes also produces characteristic log-probability curve shapes.

Ancient sands show some differences from their modern analogues, but these are usually minor. Log-probability plots of ancient sands are directly comparable to those from modern sands. The principal limitation of this study is in comparing sands formed under comparable conditions and obtaining an independent determination of the processes of formation of ancient sands.

VISHER, G. S., and HOWARD, J. D. 1974 (Jun). "Dynamic Relationship Between Hydraulics and Sedimentation in the Altamaha Estuary," Journal of Sedimentary Petrology, Vol 44, No. 2, pp 502-521.

Flood and ebb tidal cycles in the Altamaha estuary produce differing bedforms, sedimentary structures, thicknesses of sedimentary units, and grain-size distributions. Differences are the result of changes in bed shear, flow regime, and mechanisms of sediment transport.

The salt wedge developed on flood cycles produces a stratified estuary with highest flow velocity below the highest rate of salinity change. This relation results in upper flow regime as predicted by the densimetric Froude relation; trochoidal in phase waves to 2 m in height are formed. Surface waves and internal waves are seen in the salinity stratification. Ebb flow modifies the sand wave surface, and sediment transport is by ripples and dunes in the lower flow regime. Large-scale planar cross-bedding is produced by flood flow; small-scale ripple and dune structures are developed by ebb flow.

The estuary is an effective mechanism for size segregation. Suspension populations are removed by both flood and ebb flow. There is a net inland transport of suspended sediment with deposition on tidal flats and marshes. A single log-normal source population is fractionated into several differing populations by bedload transport, suspension, and recycling during successive tidal cycles. Characteristic log-probability size distributions are developed in different environments.

VIVIAN, C. M. G., and MASSIE, K. S. 1977 (Sep). "Trace Metals in Water and Sediments of the River Tawe, South Wales, in Relation to Local Sources," Environmental Pollution, Vol 14, No. 1, pp 47-61.

The concentrations and distribution of cadmium, copper, nickel, lead, and zinc have been studied in a small river and its estuary in South Wales. The river drains the Lower Swansea Valley, an area severely contaminated by smelting and other industries over the last 250 years. The high trace metal levels found in both waters and sediments result from weathering and erosion of the waste material left by those industries. As a result, the River Tawe appears to be a major source of certain metals to coastal waters of the northern Bristol Channel between Caldy Island and Porthcawl and contributes to elevated metal levels in Swansea Bay.

VOLLMERS, H. 1976. "Harbour Inlets on Tidal Estuaries," Coastal Engineering, Vol II, Chapter 108, pp 1854-1867.

The model results are in a fair agreement with the nature. But concerning the vertical distribution of velocity there are phenomena which need special investigations to explain them.

In contrariety to a vortex which is produced by a one-directional flow and which shows a good agreement between surface and bottom current, one observes different rotating systems in lateral enlargements under tidal influence.

Measurements in the entrance to the Kiel-Kanal may explain this phenomenon. Certainly in this case the density effect is of great importance. The normal velocity distribution during the tide has been measured in the Elbe River in front of the entrance. One can recognize also the displacement of the slack-water. In the surface area there is a fillstream in the entrance and near the bottom the water flows out. During the ebb tide the distribution of surface and bottom current is also quite different.

W

WANG, S. 1984 (Feb). "The Principle and Application of Sediment Effective Power," Journal of Hydraulic Engineering, Vol 110, No. 2, pp 97-107.

The concept of potential velocity is introduced in this paper to explain the principle of sediment effective power. The writer suggests a method to formulate this principle. On this basis, a new classification of moving sediment in an open channel is suggested and a description of the applications to river sedimentation is presented. The variation of von Karman constant in sediment-laden flow, the distinction between wash load and bed-material load, as well as the adequacy of sediment transportation formulas, are reviewed.

WANG, S. 1981 (Apr). "Variation of Karman Constant in Sediment-Laden Flow," Journal, Hydraulics Division, American Society of Civil Engineers, Vol 107, No. HY4, pp 407-417.

The study of the law of velocity distribution in open-channel flow carrying sediment load is one of the basic problems in the exploration of river bed development. Practice has shown that velocity distribution along the depth in sediment-laden open-channel is supposed to follow approximately the logarithmic formula of velocity distribution. In the formula there is a very important factor (K) called the von Karman coefficient. A vast amount of research works have been done by different workers on the study of the value of K .

Besides the characteristics of suspended load, the factors which have an influence on the variation of the coefficient K should also include the bottom regime of stream flow. In the study of the influence of suspension-load characteristics on the value of K , many researchers had attempted to conduct experiments under controlled bottom conditions. Owing to the complexity of the problem, however, such attempts have not been successful.

In this paper, based on the energy balance in a movable bed model without suspension load and the principle of effective power of suspension load, a formula is presented for calculating the Karman constant K in the region of main flow in an open channel carrying sediment load as given in an equation in the text.

WASTLER, T. A., and WALTER, C. M. 1968 (Dec). "Statistical Approach to Estuarine Behavior," Journal, Sanitary Engineering Division, American Society of Civil Engineers, Vol 94, No. SA6, pp 1175-1194.

The material has presented a statistical approach to the analysis of estuarine behavior. The approach is based on a sound body of data and rigorous use of statistical techniques. The example shown was ideally suited to this type of analysis.

It should be pointed out that the most glaring shortcoming of the sample shown is the length of the data record. It would have been far better to use records with about three times as many data points, but the economics and logistics of obtaining this large data bank were beyond the capacity of the project.

The results of the statistical analysis provided a rational basis for interpretation of fundamental behavior patterns in the estuary. These deductions were supported by auxiliary observations made during the time of the study. It is, therefore, concluded that the procedures discussed are a practical tool for estuarine analysis.

WEARE, T. J. 1982. "Mathematical Models," Hydraulic Modelling in Maritime Engineering, pp 15-31, Thomas Telford Ltd, London, England.

The author has made no attempt to deal with the theoretical basis of mathematical models in the limited space available. Rather, the intention has been to sketch the present range of applications and to illustrate some of the factors influencing accuracy, cost, and speed. The author makes no apology for drawing the illustrations exclusively from Hydraulics Research Station case studies in the knowledge that this will stimulate those members of the audience with other experiences to enter into the discussion.

WEATHERLY, G. L., and MARTIN, P. J. 1978 (Jul). "On the Structure and Dynamics of the Oceanic Bottom Boundary Layer," Journal of Physical Oceanography, Vol 8, No. 4, pp 557-570.

The Mellor and Yamada Level II turbulence closure scheme is used to study the oceanic bottom boundary layer (BBL). The model is tested against observations of the BBL obtained on the western Florida Shelf reported in Weatherly and Van Leer and in turn conclusions about the BBL made in that paper are tested against the model. The agreement between the model and the observations is good. The predicted and observed BBL thickness is ~ 10 m which is appreciably less than $0.4\ u_*/f \approx 30$ m, where u_* is the friction velocity and f the Coriolis parameter. The reason for the discrepancy is attributed to the BBL being formed in water which initially was stably stratified and characterized by a Brunt Vasaila frequency N_o. It is suggested that the oceanic BBL thickness should be identified with the height at which the turbulence generated in the BBL goes to zero and on dimensional grounds it is proposed that this thickness is $A\ u_*/f(1 + N_o^2/f^2)^{1/4}$, where A is a constant. The Level II model indicates that this is a good approximation over the range $0 \leq N_o/f \lesssim 200$ provided $A \approx 1.3$. Other features common to the predicted results and observations are (a) the vertical profiles of temperature and current direction which are very similar, with most of the direction changes (Ekman veering) occurring at the top of the BBL where the density stratification is largest; (b) a jet-like structure in some of the speed and direction profiles; and (c) appreciably more total Ekman veering than expected for a comparable BBL formed in neutrally stratified water.

The one-dimensional BBL formed under an along-isobath current in a stably stratified ocean is investigated for the case when the bottom is inclined relative to the horizontal isotherms. It is found that the BBL may no longer have the signature of a simple, vertically well-mixed layer because of Ekman-veering-induced upwelling (downwelling) of cooler (warmer) water in the BBL.

The profile of down-the-pressure gradient velocity component in the BBL is found to closely resemble the downslope flow of a heavier fluid discussed in Turner. The Froude number stability criteria given in Turner when applied to the Level II model results suggest that the BBL formed in a stably stratified ocean is, in a Froude number sense, stable or marginally stable on continental margins while it is unstable in the deep ocean.

WECKMANN, J. 1979. "Sediment Management at a Coastal Marina," M.S. Thesis, University of Florida, Gainesville, Fla.

A sediment management program is introduced in this study aimed at reducing siltation in coastal marinas. Briefly, this includes recognizing the modes of sediment transport, determining the accompanying siltation rates and investigating possible solutions to the siltation problem. As a case study, this program was utilized in analyzing siltation at Fernandina Beach marina, located on the northeast coast of Florida. Implementation of the program necessitated an in-depth field study to obtain the governing parameters.

The modes of sediment transport were found to be intrusion at the entrance from the adjoining waterway--a region of higher suspended sediment concentration--and piping underneath the protective bulkhead partially surrounding the basin. The suspended sediment transport mechanism was analytically investigated in order to estimate the siltation rate from the waterway. The piping mechanism was analyzed using flow net computations to determine the state of sediment intrusion underneath the bulkhead. A total sediment budget was then obtained for the marina. Solutions for the marina included redesigning the entrance utilizing the difference in flow hydrodynamics between ebb and flood tide, thereby retarding siltation in the basin, and extending the bulkhead to a depth necessary to minimize piping after redredging.

WEIL, C. B. 1977. "Sediments, Structural Framework, and Evolution of Delaware Bay, A Transgressive Estuarine Delta," Delaware Sea Grant, Technical Report DEL-SG-4-77, University of Delaware, Newark, Del.

Grain-size analyses of 411 bottom surface sediments from Delaware Bay show a distinctive pattern of progressive sorting, with grain size decreasing in the upbay direction and toward shore. The texture pattern is produced by tidal currents and is related to bathymetry. In general, the sediments become coarser-grained as water depth increases. Coarse-to-medium sands occur in the tidal channel bottoms, fine to very fine sands make up the linear sand shoals adjacent to the channels, and muds form the tidal marshes at the margins of the bay. Interlaminated muds and fine sands characterize the shallow subtidal flats, except in nearshore areas where waves and tidal currents have eroded the fine-grain marsh or estuarine sediment, exposing the underlying coarse Pleistocene sediments.

As sea level rose during the early Holocene, the locus of fine-grain estuarine deposition migrated upward and landward along the transverse shelf valley (or estuary retreat path) from the Continental Shelf to the present site of Delaware Bay. The ancestral Delaware River channel and valley behind Capes May and Henlopen began to fill with fine-grain estuarine sediments derived from the Coastal Plain and the Piedmont. With the continued rise of sea level, the active estuarine depocenter migrated north out of the bay into the tidal river, and tidal currents replaced river discharge as the dominant influence on estuarine circulation in the bay. In response to changing dynamic and physical conditions, Delaware Bay began to change from a constructive to a destructive estuarine delta, characterized by low sediment input, high tidal current energy, extensive sediment reworking, and the development of flood tidal channels. As tidal influence increased at the bay mouth, (a) bottom sediments throughout the bay became increasingly subject to reworking by tidal currents; (b) flood tidal currents eroding channels headward into the muddy substrate of the lower bay removed mud in suspension, left the coarser sands in the channel bottom as a lag deposit, and deposited fine sands along the channel margins like levees as current velocity and competence decreased at the channel margin; and (c) coarse sediments derived from the Continental Shelf were deposited in the southeastern part of the lower bay by the net landward transport of bottom tidal currents.

WEIR, R. R. 1976. "Impacts of Coastal Dredging in San Pedro Bay, California," Proceedings, Second Annual Coastal Society Conference, pp 117-128, New Orleans, La.

The remarks are concerned with the impacts of recent California conservation and environmental planning and coastal zone management legislation affecting California ports in general and the San Pedro Bay ports of Los Angeles and Long Beach in particular. The author's remarks are intended to emphasize the fact that environmentalists must consider developed ports as a unique element in a coastal zone and must develop standards for such prime national economic bases which are different from standards for pristine, undeveloped coastal areas.

WEIRICH, F. H. 1984. "Turbidity Currents: Monitoring Their Occurrence and Movement with a Three-Dimensional Sensor Network," Science, Vol 224, pp 384-387.

Detailed field data on the occurrence, flow pattern, and internal dynamics of both surge and continuous turbidity currents have been obtained with a three-dimensional array of optical and thermal sensors. The array, operated in a glacial lake in southeastern British Columbia, collected detailed information on the character of surge events with velocities reaching 110 centimetres per second and continuous underflows exceeding 90 centimetres per second. The findings (a) indicate that such currents are frequent events, occurring with density differences between the incoming stream water and the lake water as low as 0.19 kilogram per cubic meter of water; (b) document the differences in the initiation and internal characteristics of the continuous and surge events; and (c) support the concept of erosion by turbidity currents.

WELLS, J. T., and COLEMAN, J. M. 1981 (Dec). "Physical Processes and Fine-Grained Sediment Dynamics, Coast of Surinam, South America," Journal of Sedimentary Petrology, Vol 51, No. 4, pp 1053-1068.

The prograding Holocene mud wedge between the Amazon and Orinoco Rivers in the trade wind belt of northeastern South America provides a modern-day example of muds accumulating under moderate wave-energy conditions. Gigantic shore-attached mudbanks (10 km by 20 km), composed partly of thixotropic fluid-mud gel, front this coast every 30 to 60 km to form a buffer to wave attack and a temporary storage for fine-grained sediments. This mesotidal coast (tide range ~2.0 m) with gentle offshore slope (0.0006) allows the exposure twice a day of extensive tidal flat deposits, which are backed by mangrove swamps on a well-developed chenier-plain complex. Field experiments were conducted in Surinam during 1975 and 1977 to provide new information on process-form relationships in this interesting but unusual muddy environment.

Simultaneous measurements of waves, currents, tide elevation, suspended-sediment concentration, and variations in mud density show that soft intertidal and subtidal muds are suspended at both tide and wave frequency. Suspended-sediment concentrations typically exceed 1,000 mg/ℓ at the surface as incoming solitary-like waves partially disperse fluid mud into overlying water on a falling or rising tide. Redeposition of mud may occur near time of high tide. The strong attenuation of shallow-water waves by these muds provides conditions that are favorable for further sedimentation.

High concentrations of suspended fluid mud, together with solitary-like waves from the northeast throughout the year, can lead to extraordinarily high net sediment transport rates in the nearshore zone. Calculation based on solitary-wave theory and on data obtained from this study indicate that 15 to 65 by 10^6 m^3 of mud can move along shore each year without involving breaking waves, the concept of radiation stress and a nearshore circulation cell, or bedload transport. Farther offshore, outside the zone of wave dominance, wind-driven currents and the Guiana Current combine to transport muds to the northwest, consistent with the observed direction of mudflat migration.

WERNER, F., and NEWTON, R. S. 1975. "High-Energy Bedforms in the Nontidal Great Belt Linking North Sea and Baltic Sea," L. E. Cronin, ed., Vol II, pp 381-389, Academic Press, New York.

Water exchange between the brackish Baltic Sea and the marine North Sea is funneled through three channels that separate the Danish islands lying between the southern Danish peninsula and the southern tip of Sweden. The Great Belt, with a sill depth of 23 m, is the only one of these that is hydrographically important. Meteorologic anomalies over the two seas can lead to the development of strong, aperiodic pulses in the exchange between outflowing Baltic surface water and inflowing, heavier North Sea water. Currents related to these pulses are governed entirely by sea level and density differences; tidal forces play practically no role. The influence of these currents on the bottom is revealed through a wide range of bedforms developed in the thin sediment cover which overlies the glacial till basement. Sea-floor mapping with side-scan sonar showed the following bedforms to be present: (a) longitudinal forms--comet marks, sand ribbons, and sand shadows; and transverse forms--megaripples and small-scale and large-scale ripples.

These current marks are all excellent indicators of flow direction. Their distribution pattern in the Great Belt shows a definite hierarchy related to current strength, starting with small comet marks and ending with wide sand ribbons and sediment-free hard ground. Based on this scheme, maximum inflow velocities lie slightly west of the channel axis; maximum outflow velocities are found in the shallow water along the eastern channel margin.

WHITEHOUSE, U. G., JEFFREY, L. M., and DEBBRECHT, J. D. 1960. "Differential Settling Tendencies of Clay Minerals in Saline Waters," Clays and Clay Minerals, Seventh National Conference, Vol 7, pp 1-79.

Differential settling velocities of individual clay mineral types and clay mineral mixtures in quiet saline water were reported for ocean to brackish water ionic strengths, temperature range 6 to 26°C, clay mineral concentration range 0.01 to 3.6 g/ℓ, and pH range 6.5 to 9.8. The materials employed included natural deposit clay minerals and clay minerals extracted from marine sedimentary matter and from terrestrial soils.

In quiet brackish water, variations in ionic ratio composition alter the settling rates of illites and kaolinites less than 15 percent from such rates in ocean water, at constant, brackish water, ionic strength of 14 o/oo or greater. In contrast, montmorillonitic settling rates in such water varied by 40 percent or more from ocean water rates, at constant ionic strength unless the magnesium-potassium or magnesium-strontium ionic ratios of the brackish water were kept constant.

Decreasing temperatures over the range 26° to 6°C decreased settling rates (of all clay types) progressively up to about 40 percent in accordance with temperature-induced changes in the viscosity and density of the saline water medium.

The influences of fifty-seven different organic compounds or materials (carbohydrates and proteins dissolved or dispersed in the water) upon the settling velocities are cited.

The apparent interaction of illite and montmorillonite to form illitic-montmorillonitic settling entities in some clay mineral mixtures was noted. Other mixtures, exposed to artificial sea-water for 3 to 6 years, exhibited a tendency to transport 5 to 20 percent kaolinite within a developed illitic-chloritic mix, when reagitated.

Evidence is also presented to support the argument that clay minerals do not settle in single solid particulate units in saline waters. The effective settling unit, after flocculation, is described as a coacervate, i.e., as a thermodynamically reversible assembly of solid clay particles or strands within a settling solid-rich liquid unit phase.

WHITMARSH, R. B. 1970. "Precise Sediment Density Determination by Gamma-Ray Attenuation Alone," Journal of Sedimentary Petrology, Vol 41, No. 3, pp 882-883.

A difficulty arises in using the gamma-ray attenuation method to calculate the density of water-saturated high porosity sediments because the Compton mass attenuation coefficient of water differs significantly from that of common sediment forming minerals. A method is proposed to overcome this problem by a series of successive approximations to the true sediment density.

WICKER, C. F., and EATON, R. O. 1965 (May). "Sedimentation in Tidal Waterways," Evaluation of Present State of Knowledge of Factors Affecting Tidal Hydraulics and Related Phenomena, Report No. 3, Chapter III, pp 1-7, Committee on Tidal Hydraulics, Corps of Engineers, US Army; prepared by US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

The sedimentation that is taking place in tidal waterways under existing geological, meteorological, and oceanographic conditions not only causes navigation channels therein to shoal, but produces progressive deterioration of the waterway itself. Wide bays become marshy areas threaded by a maze of interconnecting shallow passages. Estuaries gradually fill outward from the banks and ultimately become expanses of marshes traversed by a meandering stream carrying the upland discharge to sea. These results do not necessarily require a geologic age for their accomplishment. It is a matter of record that numerous small tidal waterways that were of great value to the colonists of what is now the eastern seaboard of the United States are now mud flats. According to the Soil Conservation Service, due to overgrazing and cultivation of land in the contributing watershed, the present rate of deterioration of our bays and estuaries exceeds that of the early days of our history.

Although this long-term deterioration of tidal bays and estuaries may represent an ultimately greater economic loss than that represented by the present and prospective average annual cost of maintaining navigation channels in these bodies, the latter constitutes the immediate problem and is the subject discussed herein. Fortunately, channel maintenance if properly planned is compatible with preservation of the waterway itself.

WILLIAMS, D. J. A. 1980 (Mar). "Physical Properties of Cohesive Suspension and Liquid Muds," *Engineering and Environmental Applications of Cohesive Sediment Studies Workshop*, University of Florida, Gainesville, Fla.

The rheological behavior of natural cohesive suspensions is strongly influenced by physico-chemical factors such as pH, salinity, mineralogical composition, particle size, and solids concentration. This influence is largely reflected in the way in which these factors affect the flocculation process. Under typical estuarine and coastal conditions (pH 6 to 8, ionic strength ~10^{-1}M NaCl) then variation in mineralogy, size, and solids concentration will largely account for any observed variations in flow behavior.

Mud suspensions behave as pseudoplastic materials: they exhibit non-Newtonian behavior at shear rates typical of the benthic boundary layer but become Newtonian at high rates of shear. The implications for mud transport are that once eroded, mud flocs will be rapidly resuspended and conversely during periods of quiet water they will be subject to fairly rapid sedimentation.

WILLIAMSON, A. N., and GRABAU, W. E. 1974. "Sediment Concentration Mapping in Tidal Estuaries," Scientific and Technical Aerospace Reports, Vol 12, No. 20, pp 2422-2423.

An analytical procedure has been developed that considers the ERTS-1 multispectral scanner as a reflectance spectrophotometer. ADP techniques requiring only very limited computer capability are utilized to search the data defining the spectral reflectance characteristics of a scene on a pixel-by-pixel basis, identify each pixel whose spectral reflectance matches a reference spectrum, and generate maps that identify pixel locations where spectrum matches occur and identify the spectrum that was matched. If the reference spectra are known to represent a specific condition on the ground, a map of the distribution of that condition can be output as a dimensionally accurate overlay to maps of any selected scale. Two applications are described: (a) mapping the distribution of water masses exhibiting specific suspended sediment concentrations; and (b) determining the location and delineation of surface water bodies in the southeastern US. The techniques described are being successfully used to map the land area inundated by the 1973 spring flood in the Lower Mississippi River Valley, to map sediment distributions in Lake Pontchartrain (in Louisiana) as a result of opening the Bonnet Carré Floodway during the spring flood, and to inventory lakes and reservoirs.

WILLIS, D. H. 1977 (Aug). "Modelling of the Miramichi Estuary," Engineering Journal, Vol 60, No. 4, pp 20-22.

Since 1779, the ports of Newcastle and Chatham on the Miramichi estuary have served the regional economy of northeastern New Brunswick, handling between 150 and 200 ships and up to a million tons of cargo annually. Pulp, particle board, and ore concentrates are shipped, while petroleum products are unloaded for distribution to the region by road and rail.

For the first century of operation of the combined ports, the 50-km-long navigation channel from deep water in the Gulf of St. Lawrence was left in its natural condition with a limiting depth of some 5 m. As ships became larger and required deeper channels, attempts were made to improve conditions in the Miramichi, until by 1913 a minimum depth of 6.5 m and a width of 60 m had been achieved. Although ships have continued to grow since 1913, there has been no improvement in the Miramichi navigation channel. The result is that the ocean-going ships now serving Chatham and Newcastle must enter and leave port half-empty, clearly an uneconomical situation for the ports. For efficient operation, a channel depth of approximately 8 m would be required.

But industry and shipping are only part of the river's economy. The Miramichi was perhaps the best salmon river on the east coast of North America until dwindling stocks forced closure of the salmon fishery in 1972. However, there are still more than twenty commercial species in the area, including clams, oysters, and lobsters. If channel improvements are to be carried out, they must be done in such a way that fishing, and the environment in general, are not adversely affected.

In 1974, the governments of Canada and New Brunswick set up the Miramichi Channel Study to determine the technical and environmental feasibility of deepening the channel. Part of their program was an extensive series of hydraulic model tests, using both physical and mathematical models, carried out at the Hydraulics Laboratory of the National Research Council. These tests had three principal aims: (a) to determine the changes in tidal levels and currents, salinities, and wave conditions due to dredging an 8-m-deep navigation channel; (b) to to fill in the gaps in the field records of existing hydraulic conditions; and (c) to interpret the changes in hydraulic conditions as changes in the pattern of sediment movement and thus to obtain estimates of the rate of infilling of dredging channels.

WONG, G. T. F., and MOY, C., S. 1984. "Cesium-137, Metals and Organic Carbon in the Sediments of the James River Estuary, Virginia," Estuarine, Coastal and Shelf Science, Vol 18, pp 37-49.

A wide variety of sedimentary subenvironments are found within a 10-km stretch of James River including a flood dominated channel (Rocklanding Channel) and its bank (Rocklanding Shoal), a shoal with a water depth of 1 m separating two channels (Point of Shoals), an ebb-dominated channel (Burwell Bay Channel) and its bank (Burwell Bay Bank), and a tributary (Warwick River). The concentrations of Cs-137, Cu, Pb, Zn, and organic carbon in the fine-grained sediments (i.e., <63 μm) and the amount of fine-grained sediments in eight cores covering these subenvironments were determined. The sedimentation rates, estimated by Cs-137 geochronology, range from 0.4 to >3 cm year^{-1}. The sedimentation rates in the Burwell Bay region are two or more times those in the Point of Shoals and in the Rocklanding Channel and Shoal, reflecting the weaker currents in the Burwell Bay region. These sedimentation rates agree well with those obtained independently by measuring changes in the bathymetry of this area between 1873 and 1943. The concentrations of Cs-137, Cu, Pb, Zn, and organic carbon in surface sediments vary by a factor of two to three. The concentrations are higher in the Burwell Bay region, probably as a result of the higher rates of accumulation of recently formed sediments in these subenvironments. The inventories of fine-grained sediments and of Cs-137, Cu, Pb, Zn, and organic carbon accumulated since 1954 are also up to an order of magnitude higher in the Burwell Bay region. Although the concentrations of fine-grained sediments in three cores obtained in this region are similar, the inventories still vary by a factor of two to three. The inventories of Cs-137, Cu, Pb, Zn, organic carbon, and fine-grained sediments correlate well with each other indicating that Cs-137 can be a useful tracer for studying the fate of these metals and organic carbon in estuarine environments. The inhomogeneity of the concentrations and inventories of the different elements along a 10-km segment of a river suggests that a closely spaced sampling program is essential for characterizing the sedimentary provinces within an estuary. The concentrations of Cs-137, metals, and organic carbon in the coarse-grained sediments (i.e., >63 μm) are considerably lower than those in fine-grained sediments. Thus, the contribution of coarse-grained sediments to the total inventory of these elements is small.

WOODS, P. J., and BROWN, R. G. 1975. "Carbonate Sedimentation in an Arid Zone Tidal Flat, Nilemah Embayment, Shark Bay, Western Australia," Tidal Deposits, R. N. Ginsburg, ed., Section III, Chapter 26, pp 223-232, Springer-Verlag, New York.

This paper presents several distinctive tidal-flat characteristics: (a) Nilemah embayment is sheltered from the prevailing regional wave action and exposed to little tidal variation; (b) infrequent high-energy episodes leave a strong imprint on the supratidal zone--indurated crusts are broken, and resulting intraclasts spread across the flat; ripples and other structures disappear between storms; (c) dominant grain types in the tidal-flat sediments are aragonitic pellets, partly altered skeletal grains, and intraclasts; (d) algal mats provide distinctive criteria for the recognition of intertidal sediments; (e) induration is a distinctive feature, arising from prolonged subaerial exposure of the higher zones; and (f) the creation of wide intertidal and supratidal flats provides a mechanism for the development of gypsiferous sediments without the presence of extreme salinities in adjacent basin waters.

WRIGHT, L. D. 1978. "River Deltas," Coastal Sedimentary Environments, R. A. Davis, Jr., ed., Chapter 1, pp 1-68, Springer-Verlag, New York.

A sediment management program is introduced in this study aimed at reducing siltation in coastal marinas. Briefly, this includes recognizing the modes of sediment transport, determining the accompanying siltation rates and investigating possible solutions to the siltation problem. As a case study, this program was utilized in analyzing siltation at Fernandina Beach marina, located on the northeast coast of Florida. Implementation of the program necessitated an in-depth field study to obtain the governing parameters.

The modes of sediment transport were found to be intrusion at the entrance from the adjoining waterway--a region of higher suspended sediment concentration--and piping underneath the protective bulkhead partially surrounding the basin. The suspended sediment transport mechanism was analytically investigated in order to estimate the siltation rate from the waterway. The piping mechanism was analyzed using flow net computations to determine the state of sediment intrusion underneath the bulkhead. A total sediment budget was then obtained for the marina. Solutions for the marina included redesigning the entrance utilizing the difference in flow hydrodynamics between ebb and flood tide, thereby retarding siltation in the basin, and extending the bulkhead to a depth necessary to minimize piping after redredging.

Y

YALIN, M. S. 1982. "On the Similarity of Physical Models," Hydraulic Modelling in Maritime Engineering, pp 1-14, Thomas Telford Ltd, London, England.

The paper is an attempt to introduce a coherent method for the design of a Froudian model of a sediment transporting river where tidal currents may also be present (river estuary). It is assumed that the model operates with the prototype fluid (water) and that, in general, it is distorted. The model scales are determined from a set of conditions established with the aid of dimensional considerations and some expressions of loose boundary hydraulics. The method presented herein differs somewhat from that in the author's book; the information gained in recent years has made it possible to introduce certain improvements.

YARBRO, L. A., CARLSON, P. R., FISHER, T. R., CHANTON, J. P., and KEMP, W. M. 1983. "A Sediment Budget for the Choptank River Estuary in Maryland, U.S.A.," Estuarine Coastal and Shelf Science, Vol 17, pp 555-570.

A sediment budget for the Choptank River, one of the three largest estuaries on the eastern shore of Chesapeake Bay, was developed from measurements of sediment carried in upland runoff, shore erosion, sedimentation, and levels of suspended sediments in estuarine waters. Shore erosion was the major source of sediment (340 by 10^6 kg y^{-1}), contributing seven times more sediment than upland runoff. Low relief, the rural character of the Coastal Plain drainage basin, and the susceptibility of poorly consolidated shoreline materials to erosion contributed to the dominance of shore erosion over runoff as a sediment source. Box modeling indicated a net annual flux (14-44 by 10^6 kg y^{-1}) of sediment from the Choptank River to Chesapeake Bay. A mass balance estimate of sedimentation, calculated as the difference between total inputs and loss at the mouth of the estuary, (350 by 10^6 kg y^{-1}) agreed well with an estimate based on ^{210}Pb profiles (340 by 10^6 kg y^{-1}) measured along the longitudinal axis of the estuary. Lead-210 sedimentation rates correspond to accumulation rates of 1•5 to 7•9 mm y^{-1}.

YEH, H. Y. 1979. "Resuspension Properties of Flow Deposited Cohesive Sediment Beds," M.S. Thesis, University of Florida, Gainesville, Fla.

The resuspension properties of flow deposited cohesive sediment beds with non-uniform, or stratified, properties in a turbulent flow field have been investigated. The experiments were performed in a specially designed apparatus consisting of a system of an annular channel and an annular ring. A simultaneous rotation of the two components in opposite directions, at properly selected speeds, eliminates the secondary currents and generates a uniform turbulent flow field.

Kaolinite and mud samples taken from a marina near the city of Fernandina Beach, Florida, were employed as sediments. Distilled water and salt water at ocean salinity were employed as eroding fluids. It was found that the steady-state concentration varies with the bed shear stress for a given sediment in a given flow field. Mass erosion, deposition of some sediment after mass erosion, and surface erosion were observed in the investigation. The time-concentration relationship for surface erosion was found to follow an exponential law with decreasing erosion rate. The deposition process follows a logarithmic-normal law. Characteristics of mass erosion are not clear at present. It is also found that kaolinite in distilled water has a higher resistance to resuspension than in salt water. The reason for this appears to be that the shear strength within the sediment bed is higher for kaolinite in distilled water than that for kaolinite in salt water.

Z

ZEMAITIS, W. L., and COX, G. V. 1971. "Effects of Organic Enrichment Benthic Fauna in a Tidal River," Preprints, 7th Annual Conference, Marine Technology Society, pp 629-638, Washington, DC.

The field study areas of this project range from the Torresdale Filter Plant to the Camden Sewage Treatment Plant in the Delaware estuary, approximately twelve river miles. The estuary, itself, extends 128 miles from Point Liston, Delaware, north to Trenton, New Jersey, and its water quality runs the full gamut from almost healthy to severely stressed. Delaware waters are taxed by municipal contributions from densely populated areas such as Trenton, Camden, Wilmington, Dover, and Philadelphia.

At one time the water quality of the Delaware estuary was so good that a sturgeon fishing industry flourished and these fish were exported to Russia. At the present time, it is hard to say whether or not shad can migrate upstream to spawn yearly, as the Delaware water quality has integrated so much. Dissolved oxygen is high until slightly below Trenton, then it drops. Recovery occurs by the time the water reaches Torresdale Filter Plant, but this is short-lived as combined storm-sewers and wastes from chemical and other industries empty into the Delaware. Dissolved oxygen concommitant with water quality drop to the lowest levels by the time water flow has coursed through the Camden-Philadelphia urban complex. There are well over fifteen major industries alone discharging more than a million gallons of raw or partially treated wastes into the river in this region.

Suspended solids entering the estuary from pollutional sources alone were estimated to be 740,000 pounds/day. Many of these solids are biodegradable, and when the solids settle in the sediment they represent a "pollution sink." They then become relatively inactive, but if resuspended by dredging, heavy rains or benthal organisms, such as aquatic oligochaetes, the sediments can and do exert severe oxygen demands. Sedimentation is such a severe problem in the Delaware, that the Army Corps of Engineers spends over seven million dollars annually to dredge a shipping channel in the Delaware.

ZHAOSEN, L., and PEIYU, G. 1982. "Sedimentation Associated with Tidal Barriers in China's Estuaries and Measures for Its Reduction," Estuarine Comparisons, V. S. Kennedy, ed., pp 611-622, Academic Press, New York.

This paper describes the severity of sedimentation in estuaries with tidal barriers in China and explains the causes in light of changes in hydraulic conditions associated with tidal barrier construction, i.e., decrease in river flow and tidal flow and deformation of tidal waves. It discusses siltation-reduction measures now in use, including hydraulic sluicing, agitation dredging, and tidal flushing. Each method has advantages and disadvantages that make its location specific.

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